The Journal of Bone and Joint Surgery

TEN YEARS OF COLLABORATION

UNITED STATES OF AMERICA AND BRITISH COMMONWEALTH OF NATIONS

"It is a notable occasion which has brought together the orthopaedic surgeons of the English-speaking world. Yours is indeed a noble task to bring joy and hope to crippled children and to restore to a life of fruitful activity men who have been crippled by war or by the misfortunes of industry." Thus telegraphed Winston Churchill on the occasion of the first joint meeting of all Orthopaedic Associations of the British Commonwealth of Nations and the United States of America in London in 1952. This month the second such joint meeting of surgeons from the United States, Canada, Australia, New Zealand, South Africa and Great Britain is being held in Washington. The presidents of the Orthopaedic Associations of these countries will each be wearing the jewel of office conferred upon them by Queen Elizabeth the Queen Mother in London, each with the same central design of gold representing the crooked tree of Andry being made straight and with cherubs exemplifying the spirit of healing. The common purpose of all English-speaking surgeons is to unite and work together, collaborating with the surgeons of all countries to bring relief from pain, disability and suffering, and to give the calm and quietude needed by mankind—an inspiration that extends far beyond the techniques of surgery even to the problems of the world which itself is sick, crippled and disabled.

With these great ideals before us the *Journal of Bone and Joint Surgery*, after several decades during which it was nurtured and fostered by members of the American Orthopaedic Association, was freely offered to the English-speaking world. For the first time in the history of medical publication an important journal was developed on an international basis with responsibility shared by the United States of America and the British Commonwealth of Nations. The first British number included a letter from the late King George VI who had "always followed with close attention the development of orthopaedic and accident surgery and conveyed his best wishes for the success of this new venture, supported as it is by all the English-speaking peoples in collaboration for the welfare of mankind as a whole." Ten years of successful joint publication have now been completed, and a specially bound copy of the last British issue—the number dedicated to Lord Nuffield the great benefactor of orthopaedic surgery in many countries of the Commonwealth—was presented to Her Majesty the Queen, who has sent through her private secretary a message including these words:

> "Her Majesty is very glad to accept this and commands me to send her congratulations to you and all concerned on the publication of the completion of the first ten years of the Journal in which her father, the late King George, took such a keen personal interest."

Ten years of successful collaboration will be celebrated at a joint meeting of the Editorial Boards in Baltimore at about the same time as the joint meeting of the parent Associations in Washington. The English-speaking peoples are again declaring their unity of purpose and their determination to work together. Let us recall the motto from the Royal Grant of Arms of the British Orthopaedic Association which is incorporated in its own presidential jewel of office—*Recte*. The word means not only straightly but uprightly and in free translation it is beautiful, befitting, proper, appropriate, noble, good. In thus being reminded of the Hippocratic oath let us dedicate once again our work of making straight, of making straight the minds as well as the bodies of men; and let us dedicate it to be noble and good for the welfare of mankind as a whole.

EDITOR.

TENDON TRANSPLANTATION

Various operations known as tendon transplants have been performed on many patients with disability due to muscle imbalance. The results vary from brilliant success to total failure. Statistical analysis of the results of tendon transplantation yields important clinical information. For example, Gunn and Molesworth in a recent issue of the Journal (November 1957) reported on transplant of the tibialis posterior to act as a dorsiflexor in patients suffering from foot drop caused by paralysis of the lateral popliteal nerve. Although all but two of their patients were suffering from leprosy, the same clinical problem is seen after irreparable injury to the lateral popliteal nerve such as often occurs at the neck of the fibula. These patients characteristically have a foot-drop gait, and in the course of time a fixed equino-varus deformity results from the unopposed pull of the strong plantar flexor and invertor muscles of the foot. Several methods of treatment of this condition are available, such as bracing, stabilisation by posterior bone block or arthrodesis, tenodesis and tendon transplantation. The best approximation to a normal gait is produced by an operation which restores active voluntary dorsiflexion of the foot. Gunn and Molesworth report that forty-nine of fifty-six patients in whom the tibialis posterior tendon was transplanted through the interosseous membrane to the dorsum of the foot had a satisfactory result. They noted that the transplant usually functioned actively and that the patient walked well after this operation. It is well known that a tendon transplant will not correct a fixed contracture. It is therefore important that the transplant be done before deformity has occurred, or, if present, the deformity must be fully corrected before or at the time the transplant is done. The normal posterior tibial muscle is strong enough to act as a very satisfactory substitute for the totally paralysed dorsiflexors of the foot. Although it is stated that transplantation of a muscle is always accompanied by some loss in its power, this loss should be kept to a minimum by paying careful attention to the operative technique and to the post-operative régime. It is worth while during the operation to test the function of the transplant in its new position, using an electric stimulator with a sterile electrode. Among the technical problems connected with the operation there are a few of particular importance. The whole length of the posterior tibial tendon and the muscle fibre distal to the point of entrance of the muscles' nerve and blood supply must be carefully mobilised. The transplanted tendon must glide freely through the interosseous space between the tibia and fibula. An atraumatic extraperiosteal resection of the interosseous membrane minimises formation of adhesions. The new point of insertion for the transplanted tendon must be carefully chosen. If it is too far medial, the foot will develop varus, if it is too far lateral, a valgus deformity will occur. The tendon must be securely anchored to bone so that there will be adequate fixation both in the immediate post-operative period and later when the insertion is subjected to repetitive active muscle function. There is an optimum tension under which the tendon should be sutured to bone. If the tension is excessive the muscle fibres will be stretched beyond physiological limits with resultant loss in strength. If there is insufficient tension the muscle contraction will fail to produce adequate motion in dorsiflexion.

After operation the transplant must be protected from strain until its new insertion is well healed. Four to six weeks should be adequate. Although Gunn and Molesworth state that re-education of the muscle is surprisingly easy and that many patients learn to use the transplant satisfactorily with a minimum of retraining, there is considerable evidence to the contrary. The action of muscle transplants in walking has been studied by the simultaneous use of motion picture photography and electromyography.* Transplants that function well in isolated action may fail to develop proper synchronisation in walking and either cease to function or function out of phase. Normally the posterior tibial muscle in the act of walking is contracting while the dorsiflexors of the foot are relaxing and vice versa. It is illogical to expect that the transplanted muscle will automatically rephase itself. The services of a skilled physical therapist are invaluable in the retraining programme.

The paper of Singer and Fripp in this issue on Tibialis Anterior Transfer in Congenital Club Foot is of more than passing interest. These authors reviewed the results of seventy-six operations in which the anterior tibial tendon was transferred from its original insertion to a more lateral position on the dorsum of the foot in patients with relapsed club foot. There were fifty-two relapses in seventy-six tendon transfers with recurrence of equinus and varus deformity. Such deformities as cock-up of the big toe, excessive forefoot pronation and depression of the head of the first metatarsal also occurred with considerable frequency. Other authors have also reported unsatisfactory results in anterior tibial tendon transfer in club foot and it seems fair to conclude that this operation has an extremely limited place in the management of the relapsed club foot. Although it is difficult to estimate quantitatively the strength of the foot musculature in the infant or young child with a club foot, it is important to do so. The club foot that has been fully corrected by any of the accepted conservative means (Denis Browne splint or the Kite plaster technique), and that has sufficient peroneal and toe extensor power to actively abduct and dorsiflex the foot against gravity and some resistance, is unlikely to relapse. On the other hand, inability of the child to actively fully dorsiflex and abduct the foot, even if the passive motion is good, usually means that relapse will occur unless the musculature is rebalanced. Transfer of the anterior tibial tendon to a new insertion should not be undertaken if the peroneus longus is functioning. A cock-up great toe and depression of the first metatarsal head is to be expected if the balance of these antagonists is seriously disturbed. If the anterior tibial insertion is moved it should not be placed farther laterally than the fourth metatarsal. A severe pronation deformity of the forefoot is likely to occur if this rule is disregarded.

A major deforming factor in club feet is the powerful posterior tibial muscle. In one instance personally observed, a severe equino-cavo-varus deformity with forefoot adduction was converted in a growing child into a severe flat foot after transplantation of the posterior tibial tendon to the dorso-lateral aspect of the foot. It seems fair to conclude that in this instance at least, the posterior tibial muscle was the major factor in producing the club foot deformity and that transfer of the posterior tibial tendon may be a powerful tool in the correction of relapsed club feet. Further operative trial of muscle rebalancing in relapsed club feet, in spite of the discouraging reports in the literature, appears to be justified. The problems of what and when and where remain to be solved. JOSEPH S. BARR.

* CLOSE, J. R. (Oakland, California): The Phasic Activity of the Muscles of the Lower Extremity and the Effect of Tendon Transfer. American Academy of Orthopaedic Surgeons Annual Meeting, February 1-6, 1958, New York.

LEGG-CALVÉ-PERTHES' DISEASE

A Study of Late Results

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It is nearly fifty years since Calvé (1910), Legg (1910), Perthes (1910) and Waldenström (1909) independently and within a year of each other described an abnormality of the femoral capital epiphysis in children.

This present study was undertaken in order to gain further knowledge of the natural history of this condition as shown by its late results.

In the extensive literature on Perthes' disease relatively few long-term series have been published. The opinions expressed have been conflicting. Møller (1926) reviewed seventy-five hips with healed Perthes' disease—the number of long-term follow-up cases was not recorded. He emphasised that osteoarthritis might develop early, and 21·6 per cent of the patients had significant symptoms of this disorder. Legg (1927) observed forty-six patients for more than ten years. He concluded that though most of the patients would have minor symptoms of this disorder and more than half would show a persistent limp none would ever be incapacitated. Sundt (1949) reviewed 137 cases, both treated and untreated, with a follow-up of ten to fifty-two years. He agreed with Møller that Perthes' disease was not an " innocent disease," but doubted the value of treatment. Mindell and Sherman (1951) reviewed twenty-two patients after sixteen or more years: most patients had some residual defects, but even those with the worst deformity were not severely handicapped. Branciforti and Montina (1954) described the condition of twelve hips after periods averaging twenty-four years, and found that most of them were deformed. Goff, Shutkin and Hersey (1954) stated that every patient followed up for ten or more years and aged twenty or more had symptoms of joint disorder. Helbo (1954) reported fifty-two patients followed for over twenty-five years. Only eight were symptomless, the remainder having some disability with or without signs of osteoarthritis. Ratliff (1956) reviewed fifty hips followed for periods averaging seventeen years. Of these, one-third appeared normal or nearly so, a third had deformed heads but were symptomless and in about a quarter there was great loss of movement, with marked degenerative changes shown radiographically.

CLINICAL MATERIAL

The patients included in this study were all treated at the Royal National Orthopaedic Hospital.

The criteria for their inclusion were a follow-up of ten years or longer from the initiation of treatment, satisfactory clinical records and, when possible, radiographs of the condition at onset, and details of the method of treatment and after-care. Of over 200 patients with Perthes' disease treated more than ten years before, only a third were traced. This disappointing follow-up was mainly explained by movement of the population and failure to trace changes of address. It may also be ascribed to the innate dislike of the average healthy young adult of attending a hospital, particularly in the absence of symptoms. After all cases not fulfilling the above criteria had been discarded fifty-two patients were available for study. No patient with changes in the upper femoral epiphysis occurring during treatment of congenital dislocation of the hip was included. The patients attending for review were examined by the writer and their hips were radiographed.

GENERAL FEATURES

Thirty-nine patients were boys and thirteen girls—a ratio of three to one (Table I). The right hip was affected in twenty-eight patients, the left in twenty-four.

TABLE I

SEX DISTRIBUTION

Age at onset (*years*)	Number of hips affected	
	Boys	Girls
3–6	21	6
7–14	18	7

There was radiographic evidence of disease of both hips in at least six patients although in only one were the symptoms and signs present on both sides. Only the hip treated is included in this series.

The age at which treatment began varied from three to fourteen years, the commonest age being between five and eight years (Fig. 1).

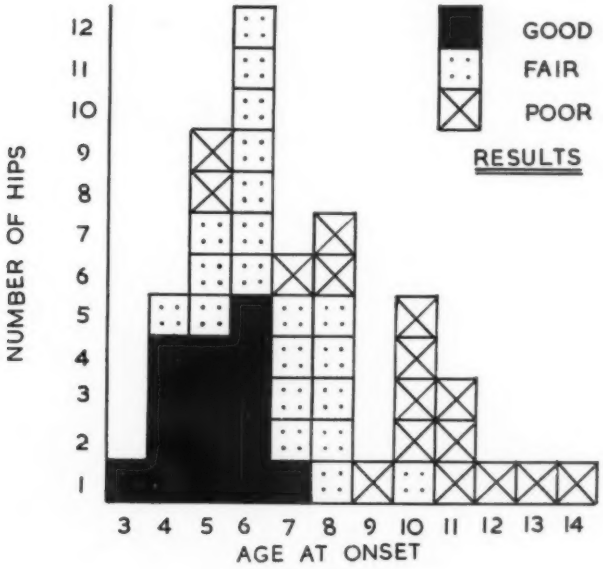

FIG. 1

Age distribution and results.

The duration of symptoms before treatment was begun varied from one to thirty-six months, the average being six months.

The routine treatment adopted was rest in bed with simple leg traction, but in four patients a plaster-of-Paris spica was employed and in two patients bed rest alone. Three patients were operated upon early, the epiphysis being drilled or grafted, but were otherwise treated with traction. The period of bed rest varied between two and twenty-four months,

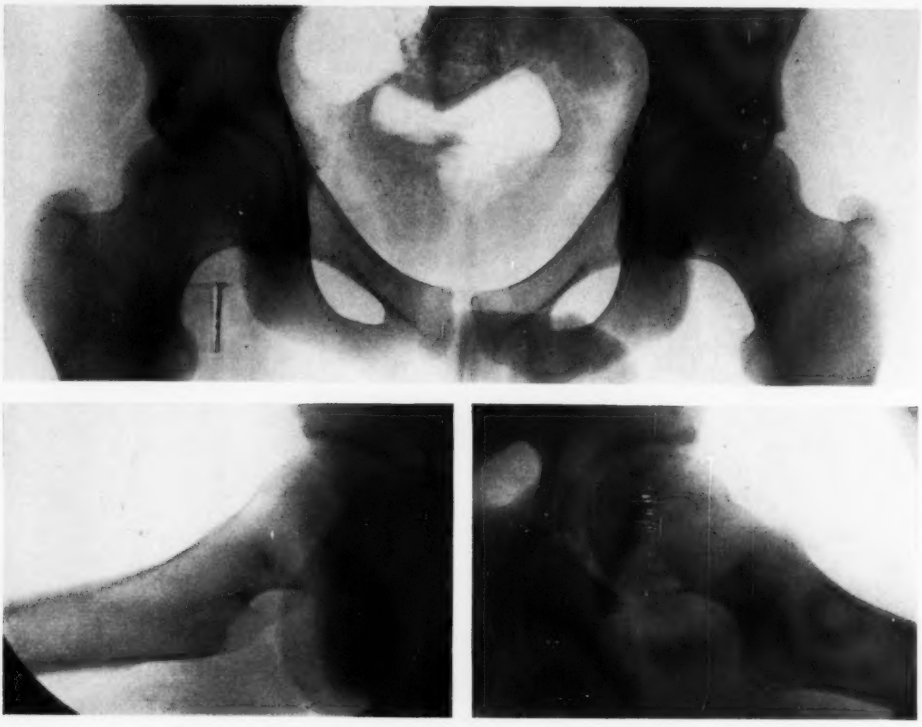

FIG. 2

Case 1—Man aged eighteen. Onset at age four years eight months. Right hip affected. Result good. Shows decreased epiphysial height and slight shortening of femoral neck.

FIG. 3

Case 2—Man aged eighteen. Onset at age five years nine months. Result fair. Shows decreased epiphysial height, slight shortening of femoral neck, posterior displacement of head on neck, and transcervical line.

the average being ten months. In all patients this was followed by the use of a weight-relieving caliper for an average period of fifteen months. The average duration of treatment was therefore ten months' traction, followed by fifteen months in a caliper—a total of twenty-five months.

The follow-up varied from ten to thirty-six years, with an average of sixteen years. The age at the most recent examination varied from fifteen to forty-two years, with an average of twenty-three years.

EXAMINATION

Symptoms—Most patients were symptomless at the time of the investigation; in the rest symptoms were trivial. Symptoms have been classified under the notation described by

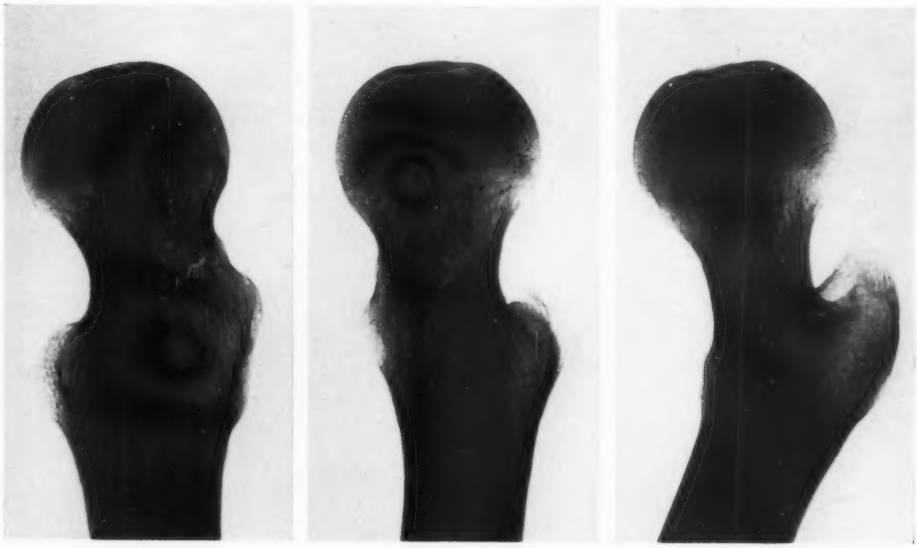

FIG. 4

Lateral radiographs of normal femur showing relation of head to neck and variations in neck-shaft angle in neutral position and in medial and lateral rotation.

Shepherd (1954): " none " (thirty-three cases), " ignores " (fourteen cases), " makes concessions " (five cases), " disabling " (no case) and " crippling " (no case). Only in the last five were activities reduced on account of the hip disorder.

Physical signs—A limp was detected in only five patients. Trendelenburg's sign was absent in all. Shortening was observed in twenty-seven patients and averaged half an inch. Some wasting of the quadriceps was present in thirty-one patients.

Movements—Twenty-five hips were fully mobile; fourteen showed 10 or more degrees of limitation of movement in one direction, three in two directions and ten in three or more directions.

The movements most commonly restricted were abduction (seventeen cases), lateral rotation (seventeen cases), extension (thirteen cases) and medial rotation (ten cases). Although some degree of extension was lost in thirteen cases, only one patient showed a flexion deformity.

An interesting finding was that medial rotation was increased by more than 10 degrees in ten hips with normal or nearly normal movements.

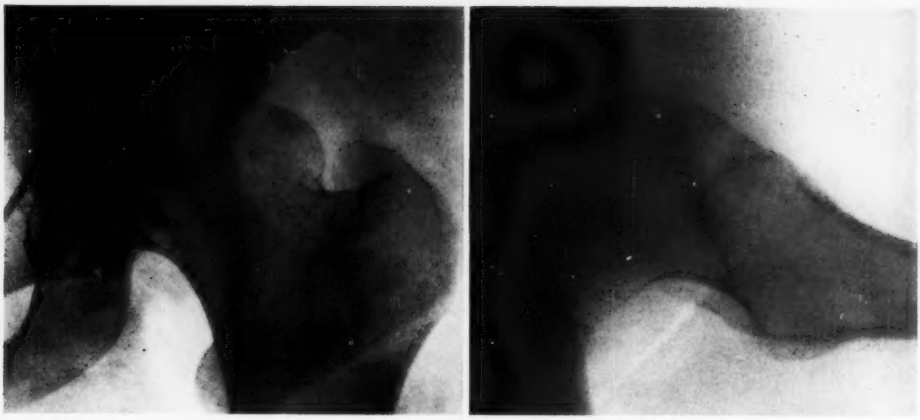

FIG. 5

Case 3—Woman aged twenty-one. Onset at age five years one month. Result poor. Shows distorted head set eccentrically on neck.

FIG. 6

Case 4—Man aged twenty-three. Onset at age eight years four months. Result poor. Shows distorted head, well marked subluxation, marked neck shortening and well developed transcervical line.

RADIOGRAPHIC EXAMINATION

Antero-posterior views of both hips on the same film, and sitting lateral views of each hip, were taken in every case.

Shape of femoral head—The shape of the femoral heads as seen in both projections conformed broadly to three categories, which have been called good, fair and poor.

Good heads (*fifteen cases*)—The outline was circular in both projections, the head was set

squarely on the femoral neck and the acetabulum was normal (Fig. 2). None of these hips showed any evidence of osteoarthritis, and without comparison with the opposite side would have passed as normal. In each case, however, the comparison revealed at least one of the following stigmata of pre-existing Perthes' disease: a large head, decreased height of the epiphysis, slight subluxation, shortening or broadening of the femoral neck.

Fair heads (*twenty-one cases*)—The outline was elliptical rather than circular in either one or both projections, but smooth and regular (Fig. 3). The acetabulum was well adapted and the head well covered. In none was there evidence of osteoarthritis.

The lateral projection of a normal head shows it set centrally on the neck whatever the degree of rotation (Fig. 4). A frequent feature of these fair heads was an eccentric position on the neck, the head appearing displaced backwards and its posterior surface even ending in an edge.

Poor heads (*sixteen cases*)—The outline was deformed in both projections. Though in eleven cases some regularity was preserved (Figs. 5 to 7), five heads were grossly deformed, the head

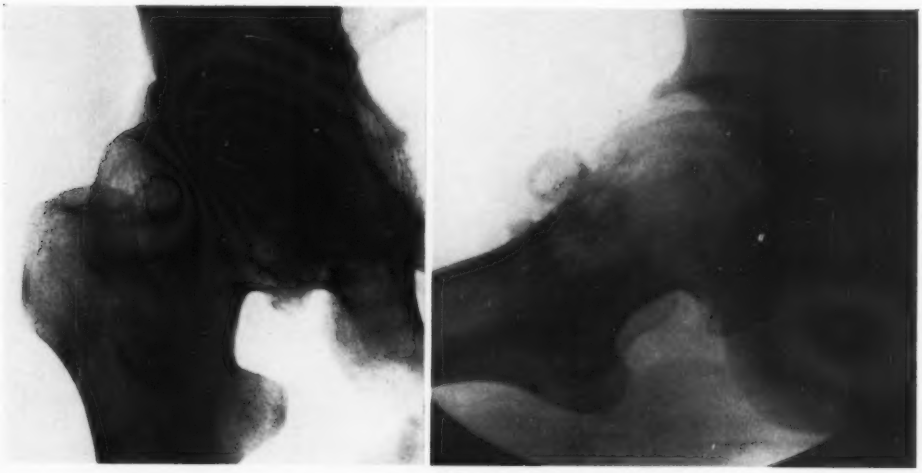

FIG. 7

Case 5—Man aged thirty-two. Onset at age eleven years ten months. Result poor. Shows distorted head, short neck and osteoarthritis with loose bodies.

appearing square in the antero-posterior and triangular in the lateral projection (Figs. 8 and 9). All showed varying degrees of osteoarthritis and in all the heads appeared displaced backwards on the neck.

Size of head—Four of the fifteen good heads were enlarged, and all misshapen heads were broader than normal.

Subluxation—Waldenström (1938) described subluxation of the hip as an early radiographic feature of Perthes' disease. This had persisted in forty-two hips. Whereas in good and fair hips it was usually minimal and often easier to see than measure, it was more pronounced in poor hips. Jonsäter (1953) concluded from arthrographic studies that increase in the head-socket distance was due not to thickening of the joint cartilage but to an inflammatory swelling of the ligamentum teres and soft tissues in the acetabular fossa which pressed the head laterally.

Shaft-neck angle—This angle was increased in twenty-five and decreased in nineteen hips compared with the normal side. Since the angle can vary with rotation by up to 25 degrees, a difference of less than 10 degrees was considered insignificant. Six hips showed valgus of this amount, but no hip showed this degree of varus.

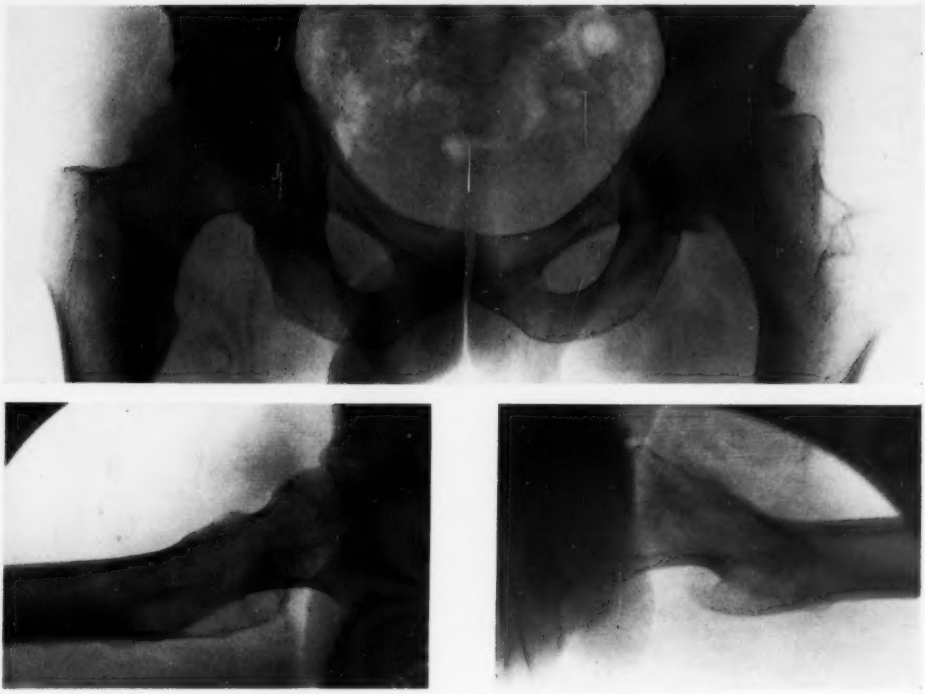

FIG. 8

Case 6—Man aged thirty-three. Onset at age fourteen years eight months. Left hip: Result poor. Shows gross distortion with squaring in antero-posterior view and triangulation in lateral view, with evidence of osteoarthritis. Right hip: Result fair (untreated).

Anteversion of femoral neck—Anteversion is notoriously difficult to measure. In a lateral radiograph of a normal hip in neutral rotation the angle between the neck and shaft represents the angle of anteversion. Though rotation affects this (Fig. 4), if both hips lie in similar rotation the radiograph will give a qualitative though not a quantitative indication of anteversion. The relation of the greater trochanter to the femoral neck is a useful guide in assessing the similarity of rotation.

Thirty-one out of the thirty-nine hips where rotation was comparable showed an increased angle of anteversion. Though increased anteversion of more than 10 degrees seldom occurred in good hips, it was frequently observed in fair and poor hips. This confirms the finding of Dunlap, Shands, Hollister, Gaul and Streit (1953) that increased anteversion is a common late radiographic finding in Perthes' disease.

Breadth of femoral neck—The breadth of the femoral neck at its narrowest section was normal in seventeen cases, increased in twenty-three, decreased in five and not measurable in the remainder. The greatest increase occurred with the most deformed heads.

Length of femoral head and neck—The frequent deformity of the head and neck precluded measurement of the true neck length. Measurement of the distance from the cortex of the head to that of the shaft in the line of the centre of the neck, however, showed this to be diminished in all but six cases. When the epiphysial scar was still visible the distance between this scar and the shaft cortex was increased in five cases, decreased in seventeen and normal in five. Reduction in head-neck length is thus caused in part by decrease in the height of the

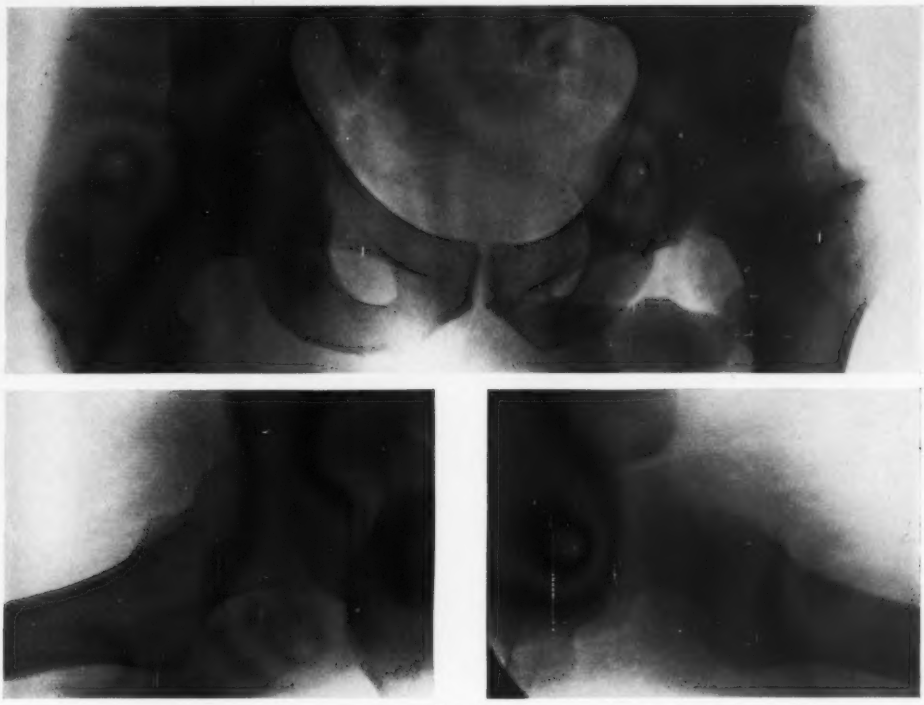

FIG. 9

Case 7—Man aged thirty-three. Onset at age thirteen years 6 months. Left hip affected. Result poor. Shows gross distortion in both views, with evidence of osteoarthritis.

epiphysis—an almost invariable finding—and also frequently by diminished metaphysial growth. The latter, however, was sometimes unaffected and occasionally increased.

Marked shortening of the head-neck segment is shown clinically by elevation of the greater trochanter.

Transcervical line—The transcervical line, a common feature of late radiographs, represents the rim of the distorted head (Fig. 6). It was observed invariably in poor hips, occasionally in fair, and never in good hips.

RESULTS

The results of treatment have been assessed solely on the final shape of the femoral head, but symptoms and mobility have been correlated with this (Figs. 10 and 11).

Good (fifteen cases)—Thirteen patients had no symptoms and two ignored them. Thirteen had full mobility and two had restriction of movement in one direction only.

Fair (twenty-one cases)—Sixteen patients had no symptoms, three ignored them and two made concessions on this account. Eleven patients had full mobility, nine had limitation of movement in one direction and one had limitation in two directions.

Poor (sixteen cases)—Four patients had no symptoms, nine ignored them and three made concessions on this account. One patient had full mobility, three patients had limitation in one direction, one patient in two directions, and eleven patients in three or more directions.

Thus with a well shaped head pain was virtually absent and mobility almost always full. With a fair head most patients were free from pain, and mobility was full or nearly so, whereas with a poor head pain of some degree was usual and mobility was nearly always markedly decreased. Clinical features therefore closely paralleled the radiographic.

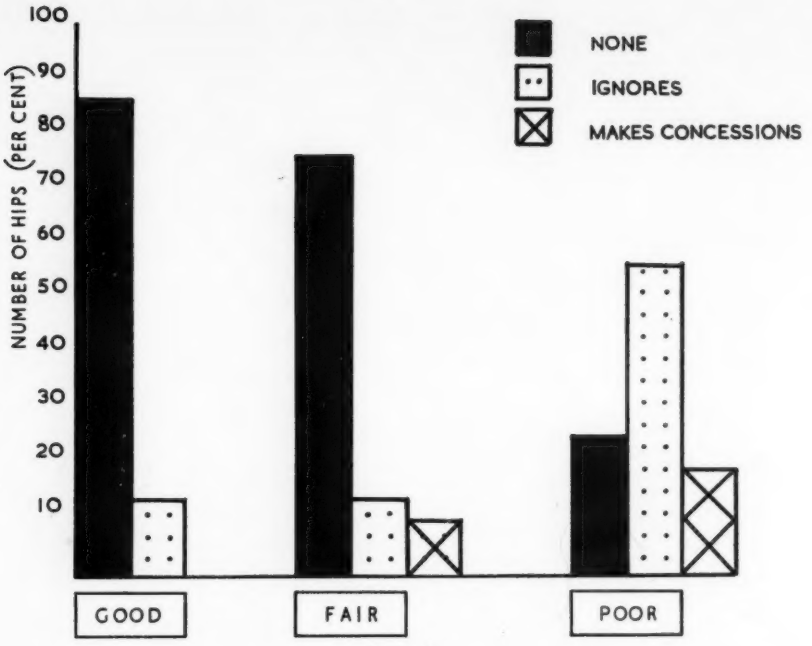

FIG. 10
Correlation of pain with shape of femoral head.

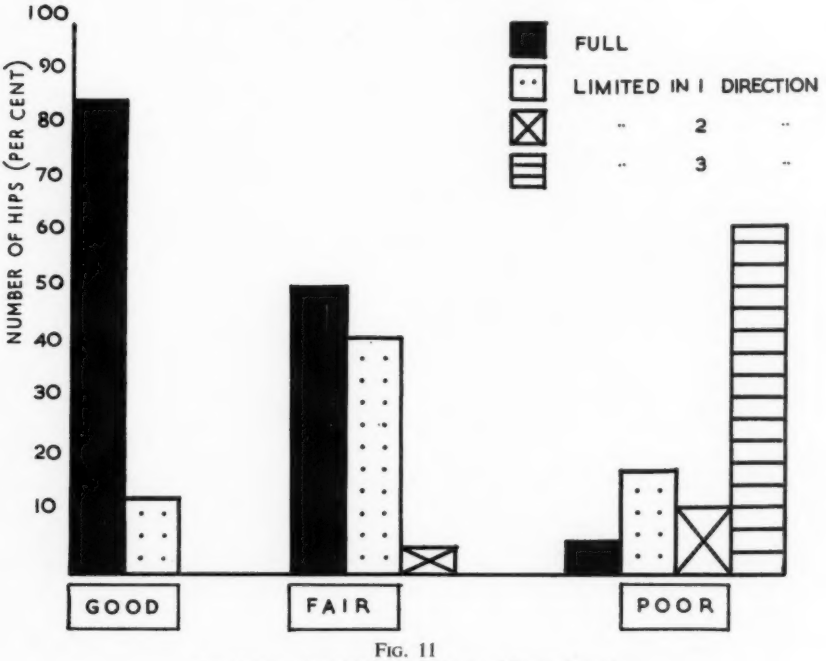

FIG. 11
Correlation of mobility with shape of femoral head.

DISCUSSION

Factors influencing the prognosis. *Age*—The age at onset of the disease is important (Fig. 1). Except in one case, a good result did not occur with an age at onset of over six, and with one exception the result was always poor if the age at onset was over eight years. *Sex*—Whereas three-quarters of the boys developed good or fair heads and one-quarter poor heads, less than half the girls obtained good or fair heads and over half had poor heads (Table II).

TABLE II

RESULTS RELATED TO SEX OF PATIENT

	Good	Fair	Poor
Boys	12	18	9
Girls	3	3	7

It thus appears that the prognosis is worse in girls, a finding that may be related to their earlier skeletal maturation.

There were insufficient series of early radiographs to determine the influence of the stage of evolution of the disease at the onset of treatment on the prognosis.

FIG. 12

FIG. 13

Case 8—Man aged twenty-six. Onset at age six years two months. Figure 12—Condition at onset: density of epiphysis, changes in epiphysial line, increased joint space and subluxation. Figure 13—At five months (a week after drilling and insertion of tibial graft). Revascularisation is commencing.

Early radiographic changes—The cycle of epiphysial changes—increased density, flattening, fragmentation and final restoration to normal texture—is a well known characteristic feature, at least in the younger patients.

Certain other features were observed. The first evidence of epiphysial flattening often occurred on the superior and lateral surfaces in the antero-posterior view, and always on the anterior surface in the lateral view. This corresponds to the main weight-bearing area of the head. The earliest evidence of revascularisation always occurred anteriorly, and most commonly laterally, sometimes medially and occasionally superiorly.

FIG. 14

FIG. 15

Case 8. Figure 14—At eleven months (six months after graft). Revascularisation is proceeding proximally. Figure 15—At nineteen months (fourteen months after graft). Revascularisation almost complete.

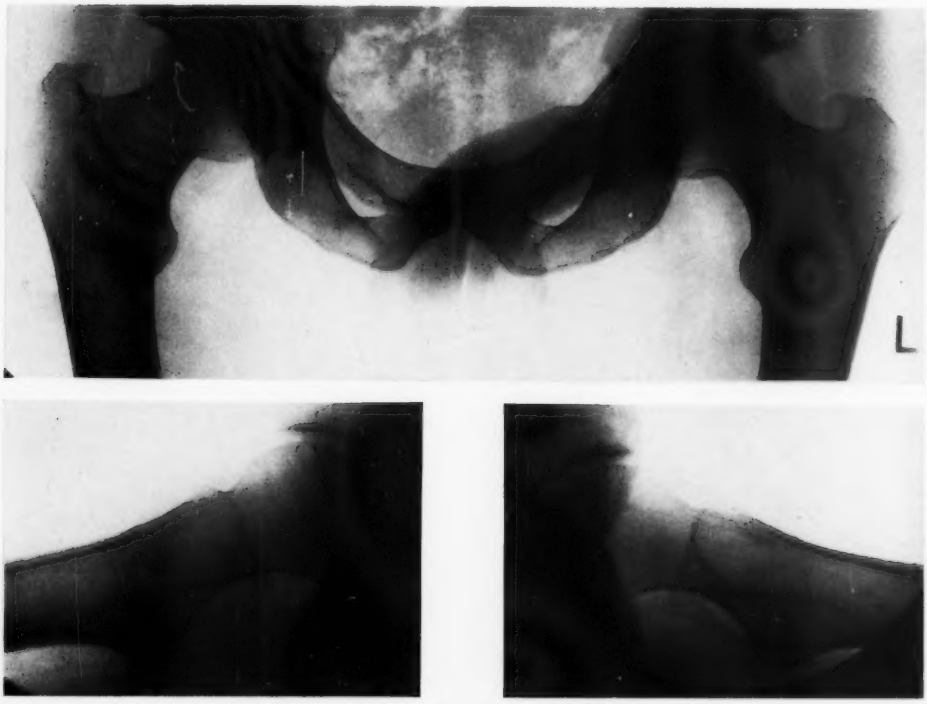

FIG. 16

Case 9—Man aged twenty-nine. Onset at age six years six months. Right hip: result fair. Left hip: result fair (untreated).

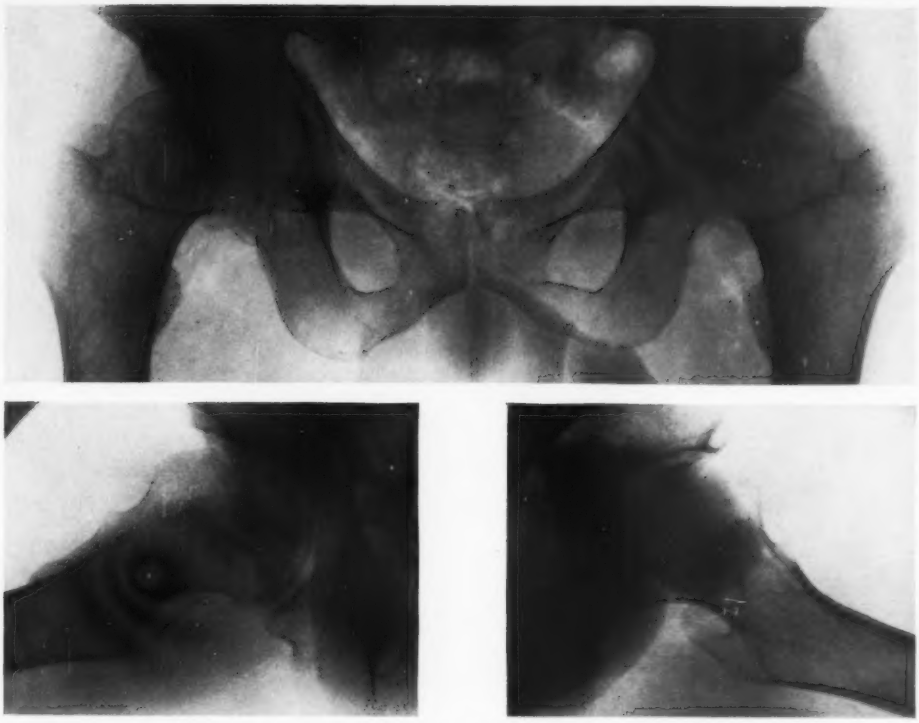

FIG. 17

Case 10—Man aged thirty-three. Onset at age eleven years four months. Left hip: result poor. Right hip: result fair (untreated).

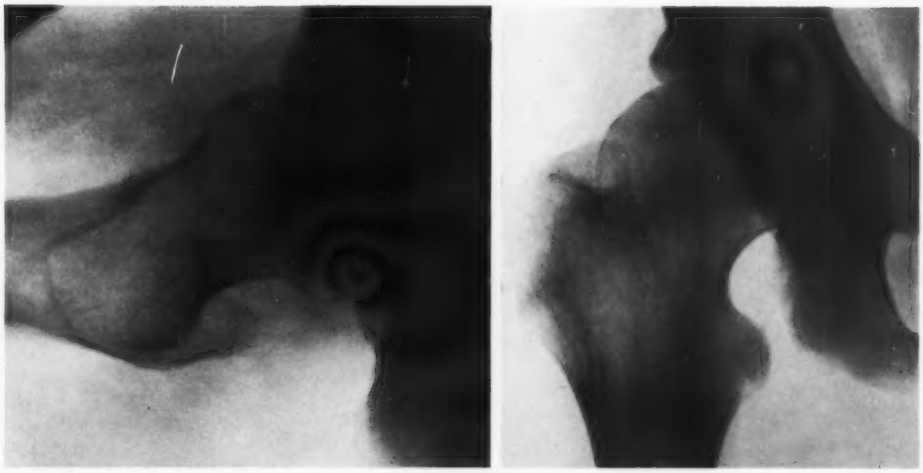

FIG. 18

Case 11—Man aged twenty-six. Onset at age seven years nine months. Result fair. Shows osteochondritis dissecans.

An antero-posterior radiograph did not give a true indication of the changes taking place in the ossific nucleus as a whole. Gross changes visible in the lateral projection were compatible with a nearly normal antero-posterior appearance.

Metaphysial changes were very variable. Though some degree of rarefaction and cystic change was common, marked rarefaction extending well into the neck often occurred. The changes, however, were of short duration; they seldom persisted for more than a year and did not appear to affect the natural progression of the disease or the late result.

Enlargement of the epiphysis and metaphysis was constant in the early stages, giving the appearance of a large head; but this inequality between the two sides usually diminished in the ensuing years.

Effect of operation—Of three patients subjected to operation by drilling and grafting, two were six and one was ten years old at onset. The two former obtained a good result and the latter a bad result. Serial radiographs of one of these showed an alteration in the usual course of the disease (Figs. 12 to 15). After the operation there appeared to be a gradual creeping revascularisation occurring proximally from the epiphysial plate. Howorth (1948) reported that early operation of this type considerably hastened revascularisation.

Affection of both hips—On radiographic examination six patients were found to have had Perthes' disease of the untreated hip. Two were mirror images of the treated hip, one good and one poor (Figs. 16 and 17). Four occurred as the pair to a square type of poor hip and were graded fair (Fig. 8). Sundt (1949) reported that each of his five cases of "quadrangular" head showed minor degrees of subluxation of the opposite side.

Of these affected but untreated hips only one had caused symptoms. Whereas two were radiographically like their treated counterpart, four were much better. There is no evidence, however, of when these contralateral changes occurred or whether the evolution of the disease in these hips was typical.

Osteochondritis dissecans—One case of osteochondritis dissecans was encountered (Fig. 18). The separated fragment was not visible as a distinct entity until at least five years after the onset of the disease, which otherwise passed through the usual changes. The separated fragment was situated on the summit of the head. Ratliff (1956) reported two such cases.

Osteoarthritis—All poor hips showed radiographic evidence of degenerative arthritis of varying severity. The femoral heads were severely deformed, and the diagnosis of osteoarthritis secondary to Perthes' disease was obvious.

The fair heads approximated more closely to good than poor, but they were definitely abnormal. Even good heads bore certain stigmata of Perthes' disease and were therefore imperfect. It seems probable that in time some of these hips will develop degenerative changes, and may well account in later life for some cases of so-called idiopathic or primary osteoarthritis.

SUMMARY

1. Fifty-two patients with Perthes' disease (affecting both hips in six instances) have been reviewed ten or more years after the beginning of treatment.
2. Judged radiographically, approximately one-third developed good, one-third fair and one-third poor femoral heads.
3. The clinical results paralleled the radiographic. Except with the worst shaped heads, function was excellent.
4. Certain constant early and late radiographic features are recorded.
5. Of the factors influencing prognosis, the age at onset of the disease and the sex of the patient appear to be important.

I wish to record my thanks to the Consultant Staff of the Royal National Orthopaedic Hsopital for permission to review their cases, and particularly to Mr H. J. Seddon for his help in the preparation of this paper. I also record my thanks to the Department of Photography of the Institute of Orthopaedics for the illustrations.

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TREATMENT IN LEGG-CALVÉ-PERTHES' DISEASE

A Comparison of In-patient and Out-patient Methods

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We have considered the hypothesis that in Perthes' disease prolonged immobilisation of the child and rest to the affected joint favourably influence the ultimate radiological appearance of the hip. An analysis of the clinical material that we now present fails to support this concept.

FIG. 1
Snyder sling as used for the children treated as out-patients.

METHOD AND MATERIAL

We have compared the results of treatment at the Hospital for Sick Children with those obtained at the Royal National Orthopaedic Hospital. At the Children's Hospital out-patient treatment with a sling (Snyder 1947) (Fig. 1) was the routine method (" out-patient " group), whereas at the Orthopaedic Hospital traction in bed followed by walking in a weight-relieving caliper was the rule (" in-patient " group).

In assessing the results of treatment note must be taken of factors known to affect the prognosis. Of these, the age at onset of the disease and the sex of the patient (Evans 1958) are important. Involvement of both hips precludes treatment by a Snyder sling and crutches.

We have consequently excluded from our review all girls, and patients of either sex with both hips affected. Since measures designed to protect the diseased femoral head from pressure have been considered valuable, it seemed important to distinguish between the patients to whom this protection could be applied early and those who attended at a later stage. We have accordingly classified our cases into ages and stages of the disease at the time of diagnosis.

Each age group spans one year. The youngest (age three) covers the period two years and six months to three years and five months; the oldest (age eight) covers the period seven years and six months to eight years and five months. The stage of the disease was designated

TABLE I

GENERAL FEATURES

	In-patient	Out-patient
Number of cases .	24	24
Stage		
Early . . .	12	12
Late . . .	12	12
Treatment		
Bed rest and traction	10 months	1 week
Caliper . . .	15 months	—
Snyder sling . .	—	21 months
Total . . .	25 months	21 months
Follow-up		
Average . .	6·75 years	4·75 years
Shortest . .	2·75 years	3·25 years

early or late. Late cases included those showing increased homogeneous density and obvious flattening of the epiphysis, and those with fragmentation, however slight. The remainder were classified as early. When the category was doubtful we were influenced by the duration of symptoms and when possible by a lateral radiograph.

From thirty-four out-patients we selected twenty-eight boys with unilateral disease. After subdivision by age and stage each radiograph was matched, hip by hip, with a radiograph of a boy of similar age and stage treated as an in-patient. The in-patient group numbered over 200, and this allowed us in most cases to select a radiograph closely comparable with that of each out-patient. We were, however, unable to pair four cases with sufficient accuracy for inclusion. This reduced the comparable groups to twenty-four, some of the features of which are tabulated above (Table I). Figures 4 to 6 show examples of such matched radiographs.

Figure 2 shows the distribution of patients in ages and stages and applies to both series.

RESULTS

A comparison was made of the most recent radiographs of each of the paired cases. Thus, as the pairs were similar in age and in the radiographic appearances of their hips at the time when treatment started, any differences revealed by the late radiographs might well be attributable to the treatment given.

The radiographic results were assessed as good, bad and intermediate. The results classified as good showed a femoral head of almost normal contour, congruous with the acetabulum and with no significant shortening of the femoral neck. A bad result infers a

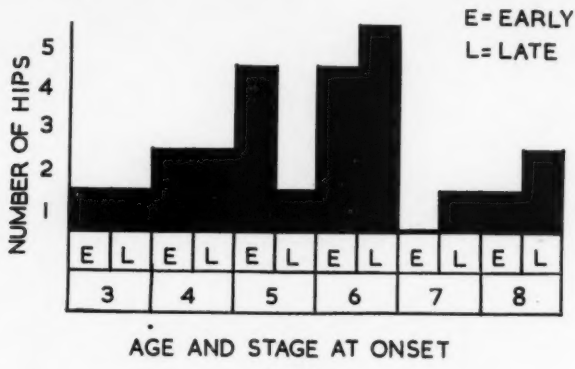

FIG. 2
Distribution of patients according to age and stage.

flattened head with lack of congruity and often subluxation or a shortened femoral neck. Radiographs showing some good and some bad features are classed as presenting intermediate results.

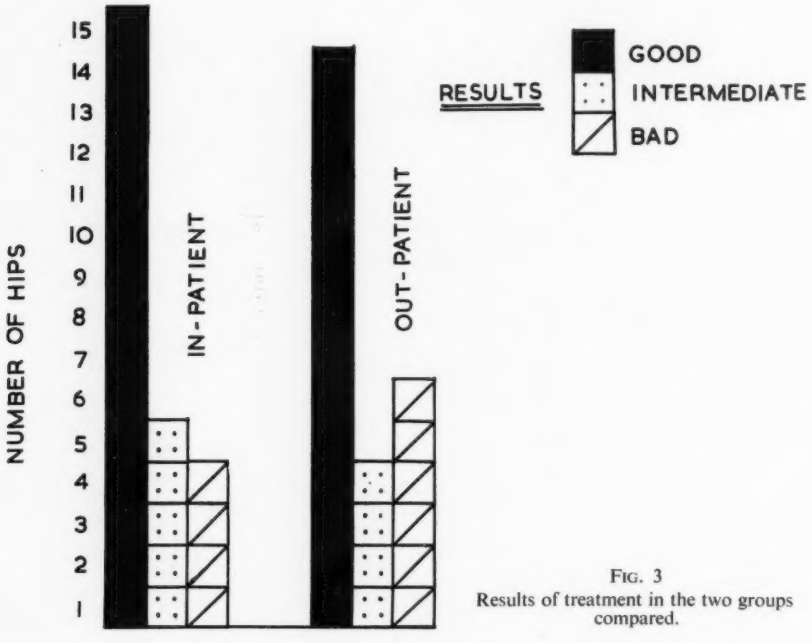

FIG. 3
Results of treatment in the two groups compared.

The results of treatment in both series are shown in Figure 3 and summarised in Table II. There is no significant difference between the two. Table III summarises the results of both methods of treatment in those cases in which treatment was begun early or late in the evolution

FIG. 4

Top—Matched radiographs at time of diagnosis. Age three years. Stage—late. *Bottom*—Later radiographs of the same patients. Ages nine and ten years. Results—good. (In-patient on left; out-patient on right.)

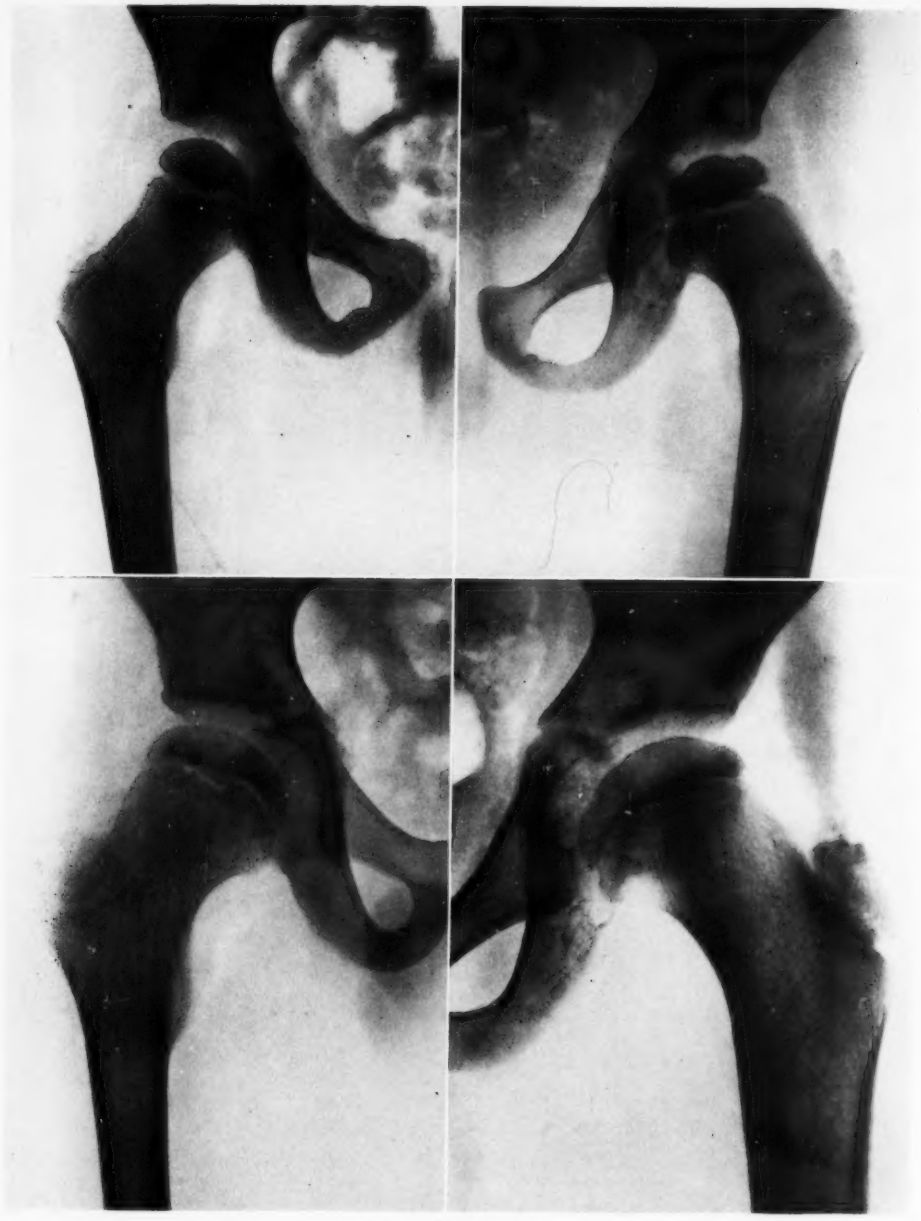

FIG. 5

Top—Matched radiographs at time of diagnosis. Age six years. Stage—early. *Bottom*—Later radiographs of the same patients. Ages nine and twelve years. Results—intermediate. (In-patient on left; out-patient on right.)

FIG. 6

Top—Matched radiographs at time of diagnosis. Age eight years. Stage—late. *Bottom*—Later radiographs of the same patients. Ages fifteen and thirteen years. Results—bad. (In-patient on left; out-patient on right.)

of the disease. The greater number of bad results in the patients presenting late is accounted for by the higher incidence of late cases in the six to eight year olds compared with the three to five.

TABLE II

RESULTS OF TREATMENT

Method of treatment	Result		
	Good	Intermediate	Bad
In-patient	15	5	4
Out-patient	14	4	6

This analysis indicates that enforced protection of the femoral head in recumbency neither favours a good result in the early cases nor improves the prognosis in the late cases when compared with a method of treatment less rigorous in every respect.

TABLE III

RESULTS OF TREATMENT ACCORDING TO STAGE OF DISEASE WHEN TREATMENT BEGAN

Stage of disease	Method of treatment	Result		
		Good	Intermediate	Bad
Early	In-patient	8	3	1
	Out-patient	8	2	2
Late	In-patient	7	2	3
	Out-patient	6	2	4

It may be suggested that an average period of ten months' immobilisation is too short for the benefits of this method to become apparent. Accordingly we would emphasise that six of the twenty-four patients were in hospital for periods of eighteen months to two years.

TABLE IV

COMPARISON OF MEAN EPIPHYSIAL INDICES OF NORMAL AND AFFECTED HIPS IN BOYS TREATED AS IN-PATIENTS AND OUT-PATIENTS

	In-patient treatment		Out-patient treatment	
Age (*years*)	Normal hip	Affected hip	Normal hip	Affected hip
	At onset of treatment			
3–6	54	38	52	38
7–8	40	25	40	27
	At follow-up			
over 7	41	28	41	29

Of these, one hip was better, one worse and four were identical with their out-patient counterparts.

It seemed prudent, however, to submit our selection and findings to further analysis.

Accordingly we have assessed the epiphysial indices (Eyre-Brook 1936) for the affected and opposite normal hips in both the early and late radiographs (Table IV). These mean indices support our belief that our cases are comparable in both selection and outcome.

It must be emphasised that this is purely a comparative radiographic study of end-results, and symptoms and signs have not been included in our final assessment. Evans (1958) has, however, shown in a far larger series, which includes some of these patients, that clinical features closely parallel the radiographic.

CONCLUSIONS

1. There is no significant difference in the final radiographic appearance of the femoral head between patients treated in hospital or as out-patients.
2. In view of this, from both a social and economic standpoint, out-patient treatment appears to be the method of choice.

Eighteen patients of the out-patient group were treated by the late Mr Eric I. Lloyd at the Hospital for Sick Children; five were treated by Mr Denis Browne and one by Mr G. H. Macnab at the same hospital. We wish to record our thanks to them and to Mr J. A. Cholmeley, Mr P. H. Newman, Mr K. I. Nissen, Mr R. Y. Paton, Mr H. J. Seddon and Mr David Trevor of the Royal National Orthopaedic Hospital for permission to review their cases.

We also record our thanks to Mr Derek Martin for the illustration of a Snyder sling.

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DISABILITIES AFTER TIBIAL SHAFT FRACTURES

With Special Reference to Volkmann's Ischaemic Contracture*

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In this paper I present the results of an investigation into the incidence, etiology and types of disability following tibial shaft fractures. The study has been prompted by the surprising scarcity of published reports on the functional prognosis after this type of injury. My observations indicate that the severity of the initial trauma is an important determinant of eventual function, and suggest that soft-tissue scarring, either from direct tissue damage or from ischaemic contracture, accounts for a considerable proportion of the bad results after fractures of the tibial shaft.

CLINICAL MATERIAL AND OBSERVATIONS

The series reported here comprises 343 soundly united tibial shaft fractures, occurring in 336 adult patients (over the age of sixteen) treated at the Royal Infirmary, Sheffield, in the six years 1948 to 1953. The duration of follow-up was from one to six years after bone union had been achieved.

Two hundred and twenty-eight patients (235 fractures) were personally examined and seventy-four others replied to a detailed questionnaire. Thirty-four patients had died or could not be traced directly; these were assessed from their hospital records, supplemented, when possible, by information from their family doctors or from other hospitals.

The results of this investigation were as follows. Two hundred and ninety-five limbs (86 per cent) had excellent functional and anatomical results. Nineteen limbs (5·5 per cent) had half an inch to three-quarters of an inch of shortening (measured radiographically). This resulted in no more than a mild "dipping" gait, often unnoticed by the patient. Eight limbs (2·5 per cent) had limitation of full knee flexion. This caused inconvenience in kneeling tasks, but was not otherwise disabling. Twenty-one limbs (6 per cent) had limitation of ankle movement or foot movement, or both. This was invariably a source of disability, with pain in the foot and leg on walking and impairment of such activities as running, dancing, and walking on irregular surfaces. Of eleven patients in this group who were engaged in heavy industry before injury, only two had been able to return to their former employment.

No example of significant varus or valgus deformity occurred in this series. Posterior angulation, occurring in three patients, was symptomless.

INVESTIGATION OF POSSIBLE CAUSES OF POST-TRAUMATIC JOINT STIFFNESS

Injury to the affected joint—There were eight patients in the whole series with associated fractures or soft-tissue injuries involving the knee joint, and these were the only patients found to have persistent limitation of knee movement. In contrast, ankle injuries complicated only two of the fractures that were followed by ankle stiffness. Moreover, a further eighteen patients with associated malleolar fractures regained full movement.

Severity of initial injury—Table I demonstrates the incidence of joint stiffness in fractures graded into minor, moderate and major severity of injury according to a simple classification previously described (Ellis 1958). The incidence of ankle and foot stiffness in these three grades

* Being the substance of part of the work accepted as a thesis for the degree of M.Ch. (Oxon).

was 1 per cent, 5 per cent and 22 per cent respectively. There was no correlation between knee stiffness and severity of injury; the condylar fractures involving the knee joint were all of moderate severity only.

TABLE I

INCIDENCE OF JOINT STIFFNESS RELATED TO SEVERITY OF INJURY

Severity of injury	Number of fractures	Cases of knee stiffness	Cases of ankle and/or foot stiffness
Minor .	98	—	1 (1%)
Moderate .	200	7 (4%)	10 (5%)
Major .	45	1 (2%)	10 (22%)
	343	8 (2%)	21 (6%)

Method of treatment—Table II shows the incidence of ankle and foot stiffness in 222 fractures treated by immobilisation alone, in 112 fractures treated by calcaneal traction and plaster immobilisation, and in nine treated by screw fixation. The fractures in each group have been subdivided according to the severity of the initial injury.

TABLE II

INCIDENCE OF ANKLE AND FOOT STIFFNESS RELATED TO THE METHOD OF TREATMENT USED

Severity of injury	Method of treatment	Number of fractures	Incidence of ankle and/or foot stiffness
Minor . .	Immobilisation .	98	1 (1%)
	Traction . .	—	—
	Screw fixation .	—	—
Moderate .	Immobilisation .	104	6 (6%)
	Traction . .	88	4 (5%)
	Screw fixation .	8	—
Major . .	Immobilisation .	20	3 (15%)
	Traction . .	24	6 (25%)
	Screw fixation .	1	1 (100%)
		343	21 (6%)

In the fractures caused by moderate violence the incidence of joint stiffness was the same whether or not traction had been employed, but in those caused by severe violence the incidence of joint stiffness was higher in the group treated by traction (25 per cent compared with 15 per cent). However, two very severe injuries are included in the fractures treated by traction, whereas there was no case of such severity in the major fractures treated by immobilisation: in both cases it was feared at first that immediate amputation might be required, but both limbs survived, eventually uniting after many months of immobilisation, and represented two of the poorest functional results in the study.

The figures for fractures treated by screw fixation are too small to be of significance; it is of interest, however, that the only patient with a poor functional result in this group sustained the one fracture of major violence treated by this method.

Infection—Five of the 105 compound fractures became infected. One of these was followed by persistent ankle and foot stiffness but this was in a fracture of major severity. Two of the 112 fractures treated by calcaneal traction were complicated by infection of the pin track, but both patients regained full joint movement.

Infection did not, therefore, account for the high incidence of persistent joint stiffness in fractures of major severity in this series.

Ischaemic contracture—Of the 225 injured limbs that were re-examined, nine were found to have one or more of the following contractures: clawing of the toes, seven examples; hallux flexus, six examples; equinus deformity, three examples. Brief details of these nine patients are given in Table III, and typical examples are illustrated in Figures 1 to 3. These contractures varied in severity from mild clawing of the toes to disabling deformities which resembled the descriptions of fully established ischaemic contractures of the lower limb (due to a variety of

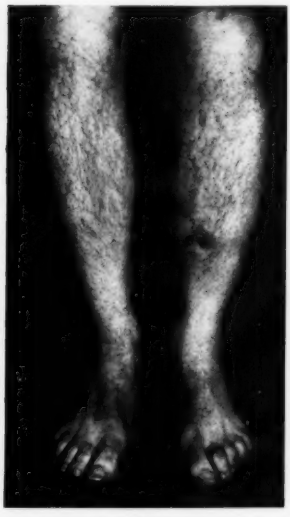

FIG. 1

FIG. 2

FIG. 3

Three examples of contractures after tibial fractures. In each case the left foot is affected and, in each, the patient is attempting to dorsiflex the ankle and toes of both legs. Figure 1—Clawing of toes with no other disability. Figure 2—Equinus deformity and limited extension of toes. Note the scar of operation for severe hallux flexus. Figure 3—A similar deformity with hallux flexus untreated.

causes) reported by Burdzik (1953), Felländer (1949), Horwitz (1940), Jones and Cotton (1935), Miller, Markin and Grossman (1952), and Salembier (1954). Seven of these nine limbs had severe limitation of ankle and foot movement and comprised a third of the cases in the series with this disability.

Six of the nine contractures followed major fractures and one other patient developed progressive contractures after two successive moderate fractures of the same leg. Six of the fractures were treated by calcaneal traction, one by internal fixation and one by plaster immobilistaion alone. The patient with two successive fractures had had the first treated by traction, the second conservatively.

ARTERIOGRAPHIC STUDIES IN THE ACUTE PHASE OF TIBIAL FRACTURES

Because of the occurrence of these contractures after fractures of the tibial shaft, it was decided to study the vascular pattern in the injured limb immediately after the injury.

Percutaneous femoral arteriography was carried out in patients with freshly sustained tibial shaft fractures, using 20 millilitres of 50 per cent Pyelosil. Rapid serial radiographs were taken, the plates being passed beneath the leg through a special casette (Jones and Steiner 1949).

Although satisfactory arteriographs were obtained in only five cases, it is of interest that three of these showed definite disturbances of major arteries. Two such disturbances occurred in fractures of minor severity, were not followed by any clinical evidence of ischaemic change, and were presumably transient. These arteriographs are reproduced in Figures 4 and 5.

TABLE III

DETAILS OF NINE CASES OF ISCHAEMIC CONTRACTURE

Case number	Age of patient (*years*)	Site	Severity	Primary treatment	Time in plaster (*weeks*)	Ischaemic manifestations	Subsequent treatment
1	16	Lowest third	Major (thrombosed posterior tibial artery)	Screw fixation; plaster	12	Wasting of calf muscles; equinus; limited extension of toes; mild hallux flexus	Lengthening of tendo calcaneus
2	41	Middle third	Major	Calcaneal traction; plaster	12	Stiff subtalar joint and forefoot; hallux flexus; clawed toes	—
3 (second fracture a year later)	59	Uppermost third	Moderate	Calcaneal traction; plaster	11	Hallux flexus	Keller's operation
(*b*)		Lowest third	Moderate	Plaster alone	13	Stiff, cold, equinus foot; clawed toes	Foot fusion; later below-knee amputation
4	20	Middle third	Major	Calcaneal traction; plaster	14	Clawed toes	—
5	35	Middle third	Moderate	Calcaneal traction; plaster	14	Limited ankle extension; hallux flexus	—
6	37	Middle third	Moderate	Plaster alone	30	Equinus deformity; stiff subtalar and forefoot joints; clawed toes	—
7	32	Lowest third	Major	Calcaneal traction; plaster	18 then further 22 after refracture	Stiff ankle, subtalar and forefoot joints; hallux flexus; foot blue and swollen	Keller's operation
8	36	Middle third	Major (posterior tibial vessels ligated)	Calcaneal traction; plaster	34	Wasting of calf muscles; stiff ankle, subtalar and forefoot joints; hallux flexus; clawed toes; leg becomes cyanosed when dependent	Hallux fusion
9	47	Middle third	Major	Calcaneal traction; plaster	23	Clawed toes	—

The third example was in a compound fracture caused by major violence; here arteriography demonstrated virtually complete obliteration of the vascular tree below the popliteal artery (Fig. 6). Exploration revealed a complete tear of the anterior tibial artery and subsequently the patient developed typical ischaemic contractures, with clawing of the toes, a plantarflexed ankle and a stiff foot (Fig. 7). The fracture in this case was treated by immobilisation in a heavily padded, widely split plaster.

ARTERIAL DAMAGE RESULTING IN GANGRENE

During the period under review six tibial shaft fractures necessitated amputation for gangrene. Four of these followed gross injuries with extensive arterial damage, but two followed relatively minor fractures. In one, the posterior tibial artery was torn midway between a minor, midshaft tibial fracture and an associated dislocation of the knee. The other was of particular interest in that, although the fracture was a closed, midshaft fracture with an intact fibula, the posterior tibial artery was found at exploration to be ruptured at the level of the fracture.

FIG. 4

FIG. 5

FIG. 6

Figure 4—Stretching and partial obliteration of the anterior tibial artery in relation to the edge of a tibial fracture. Figure 5—Obliteration of the anterior tibial artery at the level of a fibular fracture. (Filling of the peroneal artery occurred in later films.) Figure 6—Arteriograph showing all but complete arterial occlusion below the popliteal artery in a major compound fracture. Anterior tibial artery found to be divided at subsequent exploration.

One may sum up this study of vascular damage and ischaemic contracture in tibial fractures as follows. 1) Nine patients had clinical features of ischaemic contracture and seven of these had severe ankle and foot stiffness, accounting for one-third of the total examples of this disability in the present study. 2) Arteriography in acute fractures confirmed that vascular trauma at the initial injury may lead to contractures and associated foot and ankle stiffness. Moreover, it demonstrated that fractures of relatively minor severity may be associated with at least transient arterial disturbance. 3) Consideration of the cases of gangrene in this series showed, again, that serious arterial damage may accompany relatively minor fractures.

DISCUSSION

Anatomical deformity after a tibial shaft fracture is clearly a consequence of inability to reduce the fracture or to hold it reduced until sound union has occurred. In contrast, the etiology of persistent joint stiffness, a far more potent cause of disability, is less easily explained. Some examples are accounted for by direct damage to the joint itself at the time of initial injury, a factor that explained all the cases of limited knee movement in this study. Others may follow severe infection of a wound involving the joint, although there was no example of this in the series.

The part played by prolonged immobilisation in the causation of persistent limitation of joint movement is still debated. Hugh Owen Thomas and Robert Jones both stressed that immobilisation of an undamaged limb does not result in persistent stiffness, provided the joint is not kept in a position of strain, and the experimental investigations of Scaglietti and Casuccio (1936) support this view. However, in the case of an injured limb it has been suggested that prolonged immobilisation allows the organisation of traumatic exudate into firm adhesions, with resultant persistent stiffness. There is no available reported study in which the incidence of joint stiffness after tibial fracture treated by internal fixation and immediate mobilisation have been contrasted with exactly comparable cases kept immobilised until union has been achieved. Until such an investigation has been carried out it is impossible to say whether immobilisation of the injured limb, in itself, causes persistent disability, or whether any correlation between prolonged immobilisation and joint stiffness is accounted for entirely by the severity of the injury, a factor which is associated both with the incidence of joint stiffness and with delay in fracture healing (Ellis 1958).

FIG. 7

Equinus deformity, limited extension of toes and foot stiffness after the vascular injury shown in Figure 6. Patient is attempting to dorsiflex the ankle and toes.

It has been stated that damage to joints, with consequent stiffness, may occur after capsular strain or pin-track infection when skeletal traction has been employed (Wardle 1933, Jones 1936). In the present investigation there was no evidence that skeletal traction was responsible for persistent knee stiffness, because this occurred in only one patient of the 112 treated by this method. Moreover, in this solitary case there had been associated direct injury to the knee. When the incidence of ankle and foot stiffness was considered, a comparison of fractures of similar extent of injury treated by immobilisation alone and by calcaneal traction revealed little difference between comparable cases in the two groups. In contrast, there was a marked increase in the incidence of persistent joint stiffness after fractures of increasing severity of injury in both series of cases (Table II).

It has been suggested that joint stiffness after a fracture may result from associated soft-tissue injury with subsequent scarring and adhesion formation (Doran 1944, Nicoll 1941, Smillie 1951). This is supported by our findings that the incidence of joint stiffness can be correlated with the severity of the initial trauma.

I believe these soft-tissue injuries to be of two types: the direct injury, which follows severe destructive violence to the tissues, with subsequent scarring; and the indirect injury resulting from vascular damage with subsequent ischaemic changes.

In the present study no less than a third of the patients with persistent ankle and foot stiffness had clinical evidence of ischaemic contractures. The rarity of previous reports of contractures after tibial fractures, compared with the numbers found in this series, suggests that this complication has frequently been overlooked in the past.

The vascular damage in association with tibial fractures may occur in a number of ways. There may be direct injury to major arteries (Fig. 6), or the vessels may go into spasm (Cohen 1944). Such spasm, if it persists for several hours, may result in irreversible changes in the muscles (Harman 1947). Even if the spasm is then relieved, and the arterial supply of the limb appears to be normal again, permanent damage may already have taken place. Should the main arteries of the limb escape injury or spasm there may still be damage to small peripheral vessels. Clark (1945) demonstrated that the vascular supply to muscles is by an end-artery system and local vascular trauma may, therefore, be followed by areas of muscle infarction—an occurrence which has been confirmed in crush injuries by Bowden and Gutmann (1949). Muscle ischaemia may not only follow discrete arterial injury; there is also evidence that infarction and ischaemic changes may result from venous damage (Adams, Denny-Brown and Pearson 1953; Brooks 1922, Middleton 1930).

What of the occasional cases of persistent joint stiffness that occur after relatively minor injuries? I suggest that unrecognised vascular damage or spasm may, on occasion, complicate even minor fractures, and the resulting muscle ischaemia may produce sufficient scarring to cause the persistent limitation of joint movement that follows a small proportion of these injuries. If fibrosis is extensive, frank contractures will be evident, but it is suggested that subclinical examples of the consequences of muscle ischaemia may occur—that is to say, scarring sufficient to limit movement but not to produce deformity.

On the basis of the present study, therefore, I advance the following hypothesis: that persistent joint stiffness after a fracture, with no evidence of direct damage to the affected joint, is caused by replacement fibrosis consequent upon soft-tissue trauma. This damage may result from direct injury, from the ischaemia of associated vascular lesions, or from a combination of both.

SUMMARY

1. A study of the late results of 343 soundly united tibial shaft fractures was carried out. Limitation of ankle and/or foot movement occurred in twenty-one patients (6 per cent) and was found to be the most important cause of disability. Knee stiffness (2·3 per cent of cases) and shortening of up to three-quarters of an inch (5·5 per cent of cases) caused little functional impairment.

2. Stiffness of the foot and ankle was correlated with the severity of injury, occurring in 1 per cent of minor, 5 per cent of moderate and 22 per cent of major injuries.

3. One-third of the patients with limitation of foot and ankle movement had clinical evidence of ischaemic contracture.

4. It is argued that, in the absence of direct injury to the joint, persistent joint stiffness is caused by replacement fibrosis of soft tissues. This may result either from direct tissue injury or from associated vascular damage.

I would like to thank Mr F. W. Holdsworth for permission and encouragement to investigate this group of patients, all of whom were under his care.

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CORACOID TRANSPLANTATION FOR RECURRING DISLOCATION OF THE SHOULDER

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Ten years have passed since the death of W. Rowley Bristow, a leader in orthopaedic surgery and a great clinician. In his memory I present details of an operation which he showed me nineteen years ago and which I have since used exclusively for recurring dislocation of the shoulder.

A happy quality of Rowley Bristow was his ability to reduce fussy surgical problems to simple and logical essentials. This operation typifies this characteristic, for it copes more simply and logically with all the problems of the condition than the fifty-odd operations that have been discarded, and the three or four that are still practised.

Detachment of the glenoid labrum (Bankart 1938) and deformation of the head of the humerus (Hill and Sachs 1940), either singly or together, are the defects that predispose to repeated dislocation. If the glenoid labrum is detached there is nothing to stop the head of the humerus from tipping out of the shallow glenoid fossa into a synovial pouch between the neck of the scapula and the overlying subscapularis muscle. When the posterior surface of the head of the humerus is defective, the normal glenoid labrum is no longer an adequate check and the head luxates into a pouch formed in what Eyre-Brook (1948) called " stretched anterior tissues," and Osmond-Clarke (1948) " a voluminous anterior capsule." There is no mistaking the lax thin-walled anterior capsule. In the first instance, the head takes the gap medial to the glenoid labrum; and in the second, it slips into a pouch lateral to a fixed labrum. The levering force is usually an uncontrolled abduction and lateral rotation movement of the arm. When both defects become established together, the displacements take place more simply and frequently.

Only once has a different mechanism come under my observation. A young soldier reported that for as long as he could remember he had been able actively to displace and reduce the head of his right humerus. And indeed, he could demonstrate the trick with gentle movements of the arm and without lateral rotation. The shoulder had never dislocated involuntarily until he participated in a course of Army physical training. Since then he had lost control and some of the derangements had been painful. Radiographs showed a congenital flattening both of the glenoid fossa and of the medial surface of the head of the humerus. At operation it was realised that he had gradually stretched the anterior structures of the joint and that he was able to glide the flat surfaces on each other in an antero-posterior direction. The glenoid labrum was not detached but was attenuated.

On three occasions cartilaginous loose bodies, about half an inch in length, and presumably fragments of the labrum, were found in the joint. They probably precipitated the particularly painful episodes.

TREATMENT BY OPERATION

Only surgery offers a remedy for these unstable joints. When the glenoid labrum is detached, whether it is repaired by Bankart's own technique, by " Johannesburg " stapling (du Toit and Roux 1956) or by Eyre-Brook's (1948) method, the results are very good. Grafting a bone block (Palmer and Widén 1948) or a Vitallium prosthesis (Moseley 1953) to the glenoid margin can be most effective in closing the gap. When a humeral head defect and a voluminous anterior capsule are responsible, most successful results are reported from reefing the capsule (Osmond-Clarke 1948) or the subscapularis muscle (Palumbo and Quirin 1950), procedures

which limit lateral rotation at the shoulder joint, so that the bone defect in the head of the humerus cannot reach the edge of the glenoid. Indeed, when performed by competent surgeons,

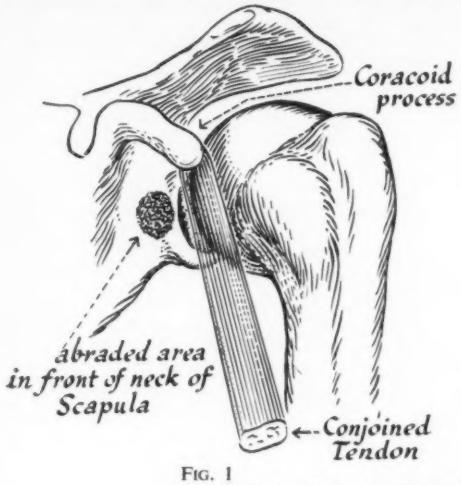

FIG. 1

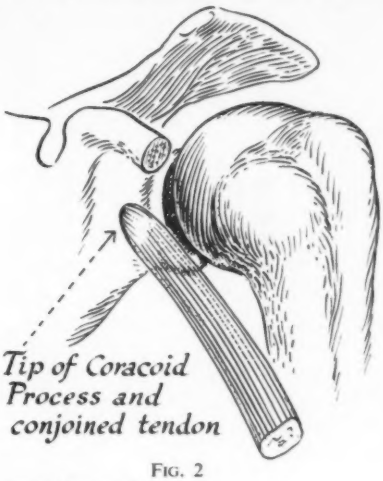

FIG. 2

Diagrams illustrating the principle of the coracoid transplant.

the Putti-Platt and the Bankart operations give results difficult to rival. But they have their technical hazards, for in some hands the joint surfaces are in risk of trauma.

The Bristow operation is logical, is easier to perform and has the added advantage that in the positions of danger —when the arm is abducted and laterally rotated—it becomes more effective.

I present this alternative procedure, therefore, for those surgeons who are not satisfied with their results from other techniques.

The object of the operation is to transplant the terminal half-inch of the coracoid process, which carries the conjoined tendons of the short head of the biceps and the coraco-brachialis, to the neck of the scapula, just medial to the antero-inferior edge of the glenoid rim (Figs. 1 and 2). After six weeks the raw bony surfaces unite either by bone or by firm fibrous tissue. The bone and the tendons form a sound buttress to the weak part of the capsule. The buttressing effect is increased when the arm is abducted or rotated laterally, because the tendons are drawn more firmly across the antero-inferior part of the capsule (Fig. 3).

FIG. 3

With the arm abducted and rotated laterally the buttressing action of the transplanted bone and tendons is very effective.

TECHNIQUE OF OPERATION

The shoulder is approached through the usual anterior deltoid incision. The cleft between the pectoralis major and deltoid muscles is widened. Exposure of the coracoid process and of the shoulder joint is facilitated by dividing part of the clavicular origin of the deltoid.

The coracoid process is divided by bone cutters immediately distal to the insertion of the pectoralis minor. The conjoined tendon is then peeled down gently as far as the entrance of the musculo-cutaneous nerve. There is no need to dissect on the medial side of the conjoined tendon, where the main axillary neurovascular bundle is vulnerable.

The wide insertion of the subscapularis muscle into the lesser tuberosity of the humerus is now displayed (Fig. 4). It is not necessary or advisable to divide the tendon completely.

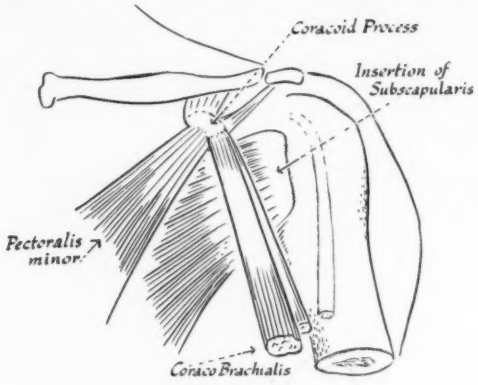

FIG. 4

Technique of operation. Exposure of coracoid process and conjoined tendon.

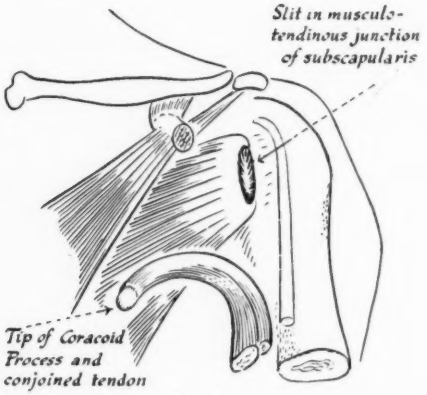

FIG. 5

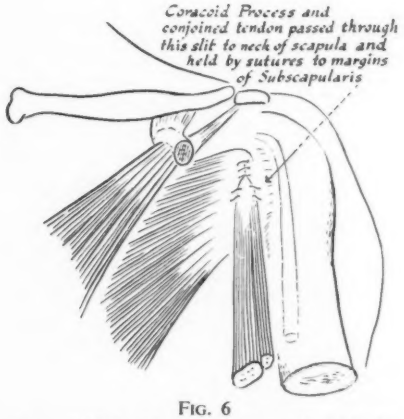
Coracoid Process and conjoined tendon passed through this slit to neck of scapula and held by sutures to margins of Subscapularis

FIG. 6

Technique of operation. Figure 5—The coracoid process has been divided and peeled downwards with the conjoined tendon. A vertical slit has been made through the tendon of subscapularis. The scapular neck is rawed through this slit. Figure 6—The coracoid process has been passed through the slit in the subscapularis, where it lies in contact with the rawed area of the scapula. The subscapularis is closed around the transplanted bone and the attached muscles.

A vertical slit, an inch or an inch and a quarter long, in the middle two-thirds of the musculo-fibrous junction of the muscle, gives adequate exposure (Fig. 5).

This incision usually opens the joint as well, for the capsule is adherent to the under-surface of the subscapularis. The joint is inspected for loose bodies. The adjacent surfaces of the capsule and subscapularis muscle down to and including the labrum must be dissected apart. The detached labrum and adjacent parts of the capsule are usually found adherent to the subscapularis muscle—an interesting finding that will be commented on later.

Once the capsule is separated from the subscapularis the bared neck of the scapula adjacent to the naked glenoid rim is exposed. When there is no gleno-labrial detachment the neck of the scapula is clothed with fairly thick periosteal tissue which must be cut and elevated to expose an area of bone about three-quarters of an inch in diameter. The opening in the capsule is sutured, and if the capsule is voluminous it may be overlapped. The surface of the bone on the neck of the scapula is rawed with a fine osteotome or gouge. The coracoid process is passed through the slit in the subscapularis and kept in firm contact with the raw area of bone by incorporating the conjoint tendon in the sutures which approximate the cut edges of the slit in the subscapularis (Fig. 6). The wound is closed.

POST-OPERATIVE CARE

The arm is supported for six weeks in a collar and cuff sling with a crepe bandage round the arm and trunk to prevent lateral rotation. After a few days, static exercises for the deltoid and upper arm muscles and use of the hand are encouraged. When the limb is released from the bandages, gentle exercises are sufficient to restore movement and power.

COMMENTS

The effect of the operation is that a block of bone plus the conjoined tendon reinforces the defective part of the joint. It is possible that in some cases the freed glenoid ligament adheres to the rawed bone on the neck of the scapula and so also repairs the Bankart lesion. In abduction and lateral rotation the conjoined tendon is drawn tauter and higher across the antero-inferior surface of the joint, so providing increasing support.

Slight limitation of lateral rotation sometimes results from this operation, but in most cases a full range of movement has been recovered. In view of the increased support provided by the tendons, full movement does not bring any danger of recurrence.

Results—Records of operations in six years of military orthopaedic surgery are no longer available to me, but I recollect only one soldier who could not return to his unit or depot in his original physical category. Reference to this patient has already been made, but whereas before the operation the head of the humerus glided out of the joint, subsequently he felt instability only over that fraction of space while the head moved from the edge of the joint to abut against the bone block. I do not yet know the answer to this particular problem, but the result does demonstrate the " bone block " effect. When there is a glenoid rim and the head must rotate over the edge, the bone block and tendon give full stability.

In Cape Town I have notes of thirty patients. Of these, five boys and one girl, all teenagers, were from a local school for epileptics. One boy redislocated the shoulder in a fit four days after the operation, but further immobilisation brought stability. Another boy, in subsequent fits, developed a posterior dislocation in the same shoulder. Of the other patients only one has suffered a further redislocation. A young athlete who had had a particularly unstable shoulder returned to all his sporting activities after the Bristow operation. One day, a year later, he was angling off the rocks for the big fish that frequent the waters near the Cape of Good Hope. His foot slipped dangerously, and in an endeavour to save himself he dropped his rod and flung up his arm. A searing pain in the shoulder preceded a recurrence of his previous insecurity. Radiographs showed that the coracoid process had been avulsed from a depression in the neck of the scapula by a violent contraction of the conjoined muscles. Operation confirmed this finding and also demonstrated that in this instance the capsule had fused with the bone and insertion of the tendons, thereby repairing the Bankart lesion. When avulsed the bone had dragged the labrum off the bone with it.

Complications—Only one complication has been worthy of note. After release from his bandages, six weeks after operation, one patient found that certain movements produced pain in the distribution of the musculo-cutaneous nerve. Later he developed mild paraesthesia on the outer surface of the upper arm. Exploration of the nerve showed that it entered the

coraco-brachialis at a rather high level and was vulnerable at the point where the muscle dipped into the slit in the subscapularis. Freeing the nerve at this point relieved his symptoms.

Management of primary dislocations—In view of the fairly general assumption that there is no tendency for the avulsed glenoid labrum to reattach itself to bone, it is interesting that at operation the detached labrum and adjacent capsule are usually found adherent to the subscapularis muscle. Torn ligamentous and capsular tissues tend to repair rapidly and profusely and to form adhesions to all surrounding tissues. In the absence of continuous immobilisation in full medial rotation, and certainly if movement is permitted, the torn edge is nearer the subscapularis and more likely to become attached to it than to the recurrently receding bony surface. Once it is united with the subscapularis there is no hope of normal repair, and moreover lateral rotation of the humerus would increase the gap through which the head luxates. This explanation reinforces Watson-Jones's (1948, 1955) adamant advice that acute dislocation should be treated by complete immobilisation in the position of full medial rotation for not less than three weeks.

SUMMARY

1. Coracoid transplantation for recurring dislocation of the shoulder is described.
2. In my experience of over thirty cases only once has true dislocation recurred after this operation. Recurrence was due to avulsion of the bone block.
3. Failure to repair the original detachment of the glenoid labrum is a frequent cause of recurrence of dislocation of the shoulder. An explanation is offered for this failure; namely that the injured labrum adheres to the deep surface of the subscapularis muscle instead of reattaching itself to bone. This reinforces Watson-Jones's advice that the original dislocation should be treated by complete immobilisation in full medial rotation for three weeks.

The illustrations are by Mr Bruce Franck of Cape Town.

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RECURRENT POSTERIOR DISLOCATION OF THE SHOULDER

Report of a Case Treated by Posterior Bone Block

SURGEON COMMANDER VICTOR JONES, ROYAL NAVY

Posterior dislocations of the shoulder are uncommon. McLaughlin (1952) found that of a series of 581 dislocations twenty-two were posterior, an incidence of 3·8 per cent, and Rowe (1956) found that ten of a series of 488 dislocations were posterior; six of them were recurrent. Cameron (1955) stated that one in seventy recurrent dislocations is posterior.

Möllerud (1946) emphasised the distinction between true traumatic dislocations and habitual subluxations. Traumatic dislocations are caused by severe injuries, often from epileptic or other seizures and often accompanied by fractures (Thomas 1937, Wilson and McKeever 1949). Habitual subluxations occur in young adults, spontaneously or as the result of minor injuries. Hindenach (1947) pointed out that, as suggested by Moullin and Keith (1904), there may be no tear of the capsule or detachment of the labrum glenoidale in this type of case; the luxation is permitted by an unduly lax capsule. Either type may be bilateral (Möllerud 1946, Arden 1956).

Several operations for the prevention of recurrent posterior dislocation of the shoulder have been described. Soft-tissue repairs have included Nicola's procedure (May 1943), reattachment of a detached labrum (Zadik 1948), and reinsertion of the divided subscapularis tendon into a defect in the anterior part of the head of the humerus (McLaughlin 1952). Failures after soft-tissue operations have been frequent, and Fèvre and Mialaret (1938) described a repair using a posterior bone graft taken from the tibia. Ilfeld and Holder (1943) used an iliac bone block in combination with Nicola's procedure. Hindenach (1947) described a case in which no defect of the labrum was present and which had recurred after Nicola's and other soft-tissue operations; an iliac bone block operation succeeded in preventing further recurrences.

The case described below is one of recurrent posterior subluxation after a blow on the front of the shoulder; a defect in the anterior rim of the glenoid labrum was found at operation but no defect in the posterior rim. The case was considered to fall into the category of habitual subluxation because there was laxity of the other shoulder. After failure of a soft-tissue operation, a successful repair was effected with a posterior iliac bone block.

CASE REPORT

The patient, a youth aged seventeen, fell from a scaffolding on to his left shoulder. The front of the shoulder was heavily bruised but the shoulder was not dislocated. A year later, when he was a National Service soldier, he was shovelling earth when he felt his left shoulder " go out " as he swung the shovel to the left. On examination he was found to have a posterior dislocation of the left shoulder (Fig. 1). This was easily reduced without anaesthesia (Fig. 2) and there was little reaction afterwards, but thereafter the shoulder subluxated every time he lifted anything heavy.

Examination showed that the right shoulder also was unduly lax. He gave the history that on one occasion, when lifting a weight-lifter's bar above his head, this shoulder had " gone out," but it had gone back as soon as someone had taken the bar from him.

A soft-tissue repair of the left shoulder was carried out. The joint was approached from behind by a deltoid-splitting incision, the teres minor muscle being divided. The posterior capsule was intact but unduly lax. When the joint was opened it was seen that the posterior

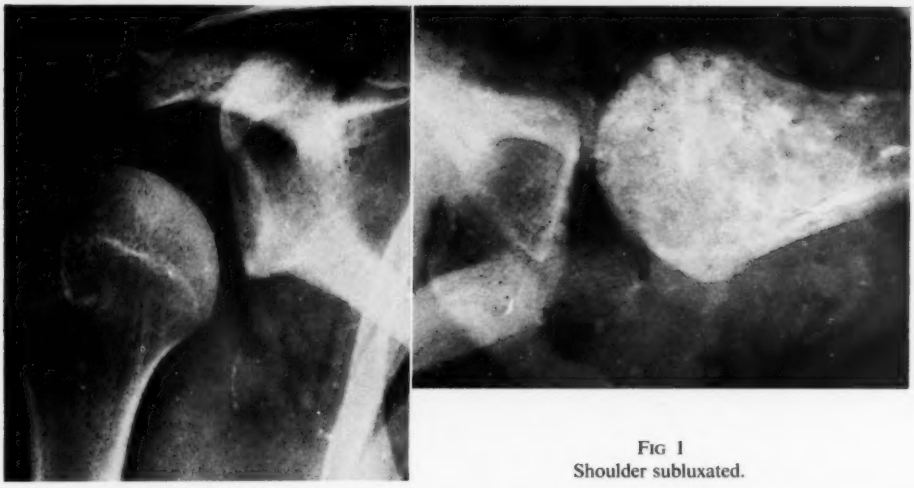

FIG 1
Shoulder subluxated.

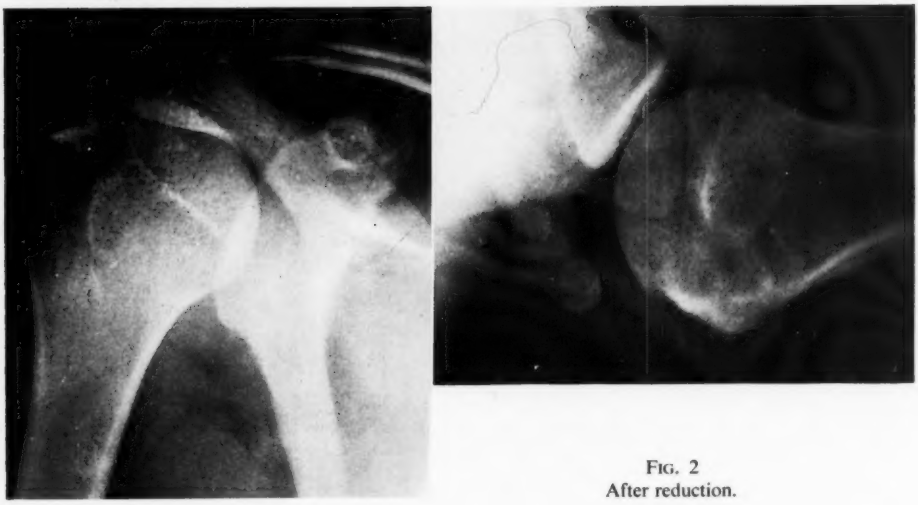

FIG. 2
After reduction.

rim of the glenoid labrum was intact, but there was a typical detachment of the anterior rim as described by Bankart (1938). There was no defect in the head of the humerus. The incision in the capsule was repaired with plication, and the teres minor was double breasted in the same way that the subscapularis is dealt with in the Putti-Platt operation. The arm was strapped to the side for four weeks.

Convalescence was uneventful but four months later, when a diesel engine he was cranking back-fired, the shoulder again dislocated posteriorly. I was asked to see him after this injury; I found that he was able to subluxate the shoulder at will and to reduce it himself. The mechanism of this phenomenon was studied under x-ray screening. It was seen that the head of the humerus moved first downwards and then backwards into a position of subluxation rather than complete dislocation. It was evident that there was marked laxity of the whole shoulder capsule.

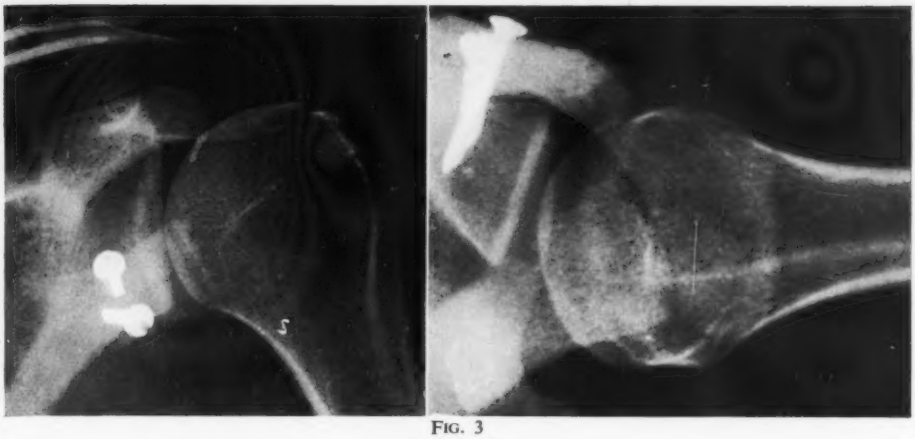

FIG. 3
Bone block.

FIG. 4

FIG. 5

FIGS. 4 and 5
Range of elevation and of medial rotation four months after operation.

Operation—A posterior bone block operation was done, the technique being like that described by Hindenach. The shoulder was approached from behind, the deltoid being split and the joint exposed in the interval between infraspinatus and teres minor. The capsule was opened and it was confirmed that there was still no defect in the posterior rim of the glenoid. After closure of the capsule with plication—a step which seemed to add nothing to the stability of the joint—a piece of bone $1\frac{1}{2} \times 1$ inch was cut from the outer table of the left iliac crest and screwed to the back of the neck of the scapula. It was placed postero-inferiorly with a quarter of an inch of bone overlapping the outer margin of the glenoid (Fig. 3). After closure of the wound the arm was bandaged to the side; next day it was put up on an abduction frame with 45 degrees' abduction and 45 degrees' lateral rotation. This position was maintained for four weeks.

Convalescence was uneventful. Four months after operation he had regained a full range of shoulder movements (Figs. 4 and 5), and nine months after operation he was free from symptoms and had no weakness or instability of the shoulder. All movements remained full.

DISCUSSION

Posterior luxation of the shoulder may be permitted by three types of deficiency of the posterior part of the capsule—a tear of the capsule, detachment of the posterior rim of the

FIG. 6
Horizontal section of left shoulder from above showing attachment of the capsule.

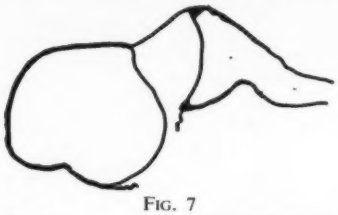

FIG. 7

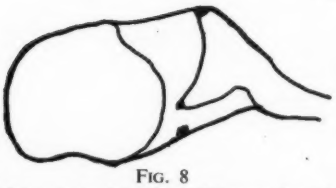

FIG. 8

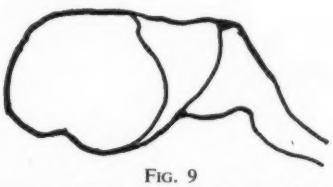

FIG. 9

Three mechanisms by which posterior subluxation of the shoulder may be permitted. Figure 7—Torn capsule. Figure 8—Torn labrum with stripping of capsule from neck of scapula. Figure 9—Lax capsule.

glenoid labrum with stripping of the capsule from the neck of the scapula, or undue laxity of the capsule (Figs. 6 to 9). In this case the fault was undue laxity of the capsule, assisted by a defect in the anterior rim of the glenoid. The first two types of lesion may be expected in cases of true dislocation after major injury; in these, repairs on the lines of Bankart's operation may well be successful. In habitual luxations associated with laxity of the capsule,

however, soft-tissue operations are less likely to succeed. In this type of case a posterior bone block gives a satisfactory result. It does not produce the limitation of rotation—in this case medial rotation—that occurs after a considerable proportion of Bankart and Putti-Platt operations. The outer table of the iliac crest furnishes a piece of bone that is well adapted to the curves of the neck of the scapula.

Although in the case described above the capsule was opened and plicated, this step was probably unnecessary and contributed nothing to the stability of the joint.

SUMMARY

1. A case of recurrent posterior subluxation of the shoulder is described. After failure of a soft-tissue repair, a posterior bone block operation was performed.

2. The distinction between traumatic dislocations with tearing of the capsule or of the glenoid labrum, and habitual luxations from laxity of the capsule, is emphasised. Although the anterior rim of the glenoid was detached in this case, it is considered to fall into the latter category.

3. A posterior bone block provides a simple and efficient form of repair in this type of case. It is free from the disadvantage of causing limitation of rotation at the shoulder joint; it employs a principle which might well merit more application than at present in the repair of anterior dislocations.

I wish to thank the Commanding Officer of the 33rd General Hospital, Kowloon, Col. J. W. A. McIver, R.A.M.C., for permission to publish this report and Lt.-Col. I. M. Grant, R.A.M.C., for encouragement and help in preparing the paper.

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OSTEOPETROSIS WITH SYNDACTYLY

A Morphological Variant of Albers-Schönberg's Disease

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Osteopetrosis is characterised by a generalised increase in density of the bones to x-rays (Albers-Schönberg 1904, 1907). This abnormality corresponds to an increased specific gravity of the bones, but the proportions of calcium, phosphate and collagen are within normal limits (Enticknap 1954). Histological appearances support the belief that the increased density is caused by excessive packing of the bones with osseous tissue and calcified cartilage at the expense of connective tissue. It has been suggested that the primary fault is deficiency of osteoclastic activity (Weinmann and Sicher 1955), which would explain also the deficient bone remodelling that is usually present to some degree.

Osteopetrosis is congenital, and may be sporadic or hereditary (Hanhart 1948, Thomson 1949). Usually it is inherited as a Mendelian recessive characteristic, sometimes as a dominant (McPeak 1936, Nussey 1938). The disorder begins *in utero* in some cases (Zawisch 1947, McCune and Bradley 1934), but in others it has been observed to develop during childhood (Kneal and Sante 1951). Age at diagnosis has varied from before birth (Jenkinson, Pfisterer, Latteier and Martin 1943) to seventy-three years (Fairbank 1951). In severity the disease ranges from a " malignant " form, with severe neurological and haematological complications and compatible with only a few months or years of life (McPeak 1936, Nussey 1938), to the " benign " form which has a normal life span (Hinkel and Beiler 1955). Although the bones are usually hard, Pirie (1933) described a case with " chalky bones." The fragility of the bones is sometimes increased, with a tendency to multiple fractures (Fairbank 1951), but in many subjects the bones have normal strength or even increased resilience (Enticknap 1954).

Usually the serum calcium, phosphorus and alkaline phosphatase levels have been within normal limits. There have been exceptions in cases with associated rickets (McCune and Bradley 1934), parathyroid adenoma (Péhu, Policard and Dufourt 1931), or generalised soft-tissue calcinosis (Schulze 1921). Recently five patients have been reported with raised serum acid phosphatase (Kessel and Signy 1956). As this enzyme was not determined in the older cases it is not yet known whether it is usually raised, but certainly two reported patients (Seigman and Kilby 1950, Hinkel and Beiler 1955) had normal levels.

Two rare diseases have been described which have some features in common with Albers-Schönberg's disease and are also thought to be due to developmental errors. " Craniometaphysial dysplasia " (Jackson, Albright, Drewry, Hanelin and Rubin 1954) has increased bone density restricted to the skull and face combined with abnormal metaphysial moulding as found in familial metaphysial dysplasia (Pyle's disease). Thickening of the face and calvarium is greater than is usual in osteopetrosis. Engelmann's disease (Engelmann 1929, Griffiths 1956) shows increased density and thickening confined to the diaphyses usually of the large limb bones, often associated with increased density of parts of the skull.

A variant of osteopetrosis which has occurred in four different families is exemplified by the two cases described here and by five others found in the literature. The outstanding feature of this syndrome is the association of syndactyly with osteopetrosis, but in addition there have been: 1) atrophic distal phalanges; 2) thickened shafts of metacarpals and metatarsals; 3) thickening of the skull vault, facial bones and mandible, producing a mild degree of leontiasis ossea; and 4) marked thickening of the clavicle in some cases. The first

FIG. 1
Case 1—Photograph showing the facial features.

FIG. 2
Case 1—Photograph of the hands showing syndactyly between the index and middle fingers.

three abnormalities have not been described as features of osteopetrosis, and the last two are uncommon in the standard form (Fairbank 1951, Hinkel and Beiler 1955, Jackson *et al.* 1954). In three of the four families there were affected siblings; in two families the patients were children of first cousin marriages—strongly suggesting recessive inheritance.

CASE REPORTS

Case 1—A white girl aged eight years was studied at Groote Schuur Hospital in 1953. She developed normally until the second year of life, when a right facial palsy suddenly appeared. Facial weakness subsequently became bilateral. Although a bright child, she never learned to speak. She had no fractures or other illnesses. The parents were alive and well, but were separated and not interviewed. The three older siblings were well, of normal intelligence, not deaf and said to be free of syndactyly. Only one was examined.

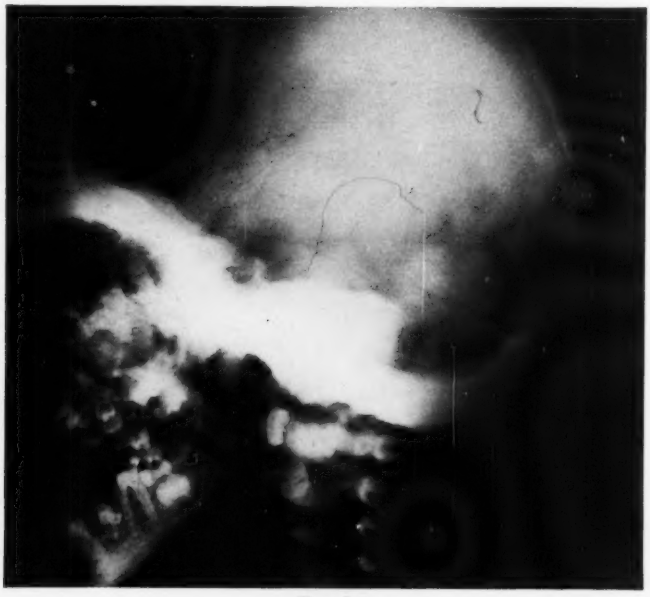

FIG. 3
Case 1—Skull.

On admission the patient was 4 feet 4 inches tall. Her weight increased from 67 to 81 pounds while she was in hospital. She was completely deaf and inarticulate. Making allowance for this, her intelligence appeared normal. Her head was dolichocephalic and the forehead prominent. The face was long with widely spaced eyes (Fig. 1) and a protuberant lower jaw. She breathed through her mouth and had bilateral lower motor neurone facial palsy. A markedly thickened right malleus was seen on otoscopy. There was no optic atrophy. The proximal phalanges of the index and middle fingers of both hands were joined by a web. There were no nails on the index fingers (Fig. 2). Blood pressure was 120/80 millimetres Hg. The liver edge was firm and palpable two finger-breadths below the costal margin. There was no other abnormality on clinical examination. The cells in the peripheral blood were normal. The urine contained a little protein intermittently but no other abnormal constituent.

Radiographic examination—The whole skeleton was radiographed. Every bone in the body showed increased density. There were no fractures. The appearances were typical of osteopetrosis. The whole skull was very dense (Fig. 3). Its base was greatly thickened and

FIG. 4
Case 1—Humeri.

FIG. 5
Case 1—Hands.

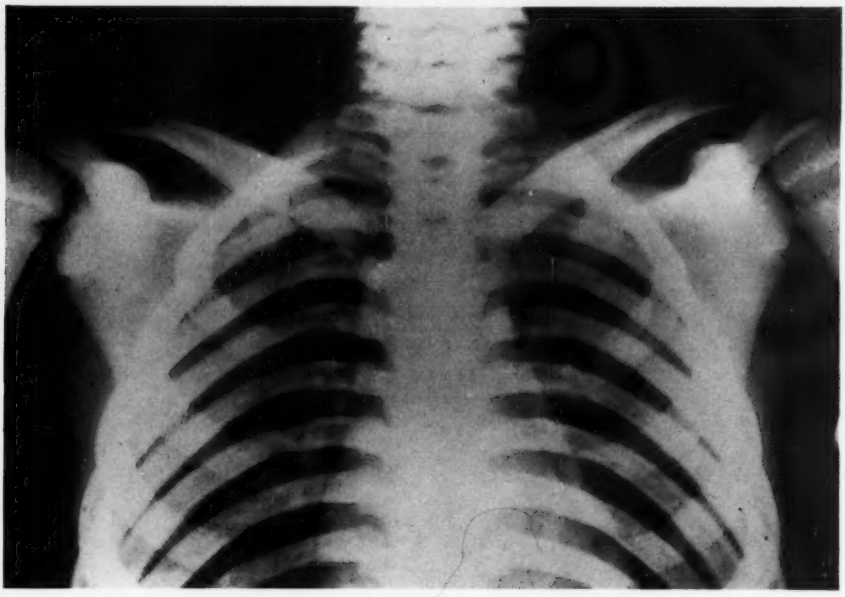

FIG. 6
Case 1—Clavicles and ribs.

FIG. 7
Case 1—Pelvis.

FIG. 8

FIG. 9

Case 1—Femora and tibiae.

FIG. 10
Case 1—Feet.

the vault moderately. The facial bones and mandible showed increased density. The long bones of the upper limb had abnormally thick shafts (Fig. 4), and the metacarpals appeared oblong, lacking the normal tubulation of their shafts. A similar diaphysial thickening was present in the phalanges, but the distal phalanges of the index fingers were hypoplastic (Fig. 5). The clavicles were greatly thickened (Fig. 6), but the modelling of the ribs was within normal limits. The pelvis and upper femora showed uniform greatly increased density (Fig. 7). In the lower halves of the femora the density was about normal but there was no demarcation into cortex and medulla, there were " celery-stalk " longitudinal striations, and the metaphysial region was somewhat splayed (Fig. 8). Like the femora, the tibiae and fibulae showed a fading off of the increased density in their lowest thirds, combined with some broadening of their lower metaphyses. About seven transverse growth lines were well seen in the lower tibiae (Fig. 9). In the feet the metatarsals showed thickening of shafts like that seen in the metacarpals, and the tips of the distal phalanges of the big toes were hypoplastic (Fig. 10).

Haemopoietic and histological studies—Marrow was easily obtained from one iliac crest by needle aspiration, and the haematopoietic cells appeared normal. A biopsy was taken under general anaesthesia from the diaphysis of one tibia. Histological section showed dense lamellar bone in which a superabundance of osteocytes was present but no Haversian systems (Dr G. Selzer).

Biochemical and other investigations—The serum calcium ranged between 8·6 and 10·3 milligrams per 100 millilitres and inorganic phosphorus between 4·1 and 5·2 milligrams per 100 millilitres. Urinary Sulkowitch test was normal. The serum alkaline phosphatase ranged between 17·5 and 23·5 (Shinowara) units per 100 millilitres (six determinations). The blood urea was between 27 and 40 milligrams per 100 millilitres on four occasions (but was 73 milligrams on one occasion). Urea clearance (maximum) was 85 and 74 per cent. The following investigations were normal: intravenous pyelogram, phenolsulphonphthalein excretion, urine culture; serum proteins, thymol turbidity and flocculation, serum sodium, potassium and chloride, bilirubin, cholesterol and Wassermann reaction; cerebro-spinal fluid, air encephalogram and electroencephalogram.

Case 2—A white girl of thirteen years was admitted to Groote Schuur Hospital in 1956 for gradually progressive deafness which had been worse since an attack of bilateral otitis media three months before. Two months before admission, left facial weakness appeared. She had never had any fracture. Deformity of her fingers had been present since birth. Her parents were first cousins. There was a family history of syndactylism in her grandmother and only (younger) brother, but none of fractures, deafness or facial asymmetry.

On examination, height, physical development and proportions were normal. Apparent mental slowness was probably due to severe deafness, since she was a keen reader. She had a heavy facial appearance (Fig. 11) with prominent forehead, widened nasal bridge and very thick mandible. In addition there was a left lower motor neurone facial paresis. The teeth were not mottled. There was cutaneous syndactylism between the left ring, middle and index fingers and between the right index and middle fingers (Fig. 13). Both index fingers appeared to have only two phalanges, with the distal ones angled outwards. Most of the nails were short except for that of the left index finger, which looked like a thumb-nail. In the feet there was partial cutaneous syndactyly between the left fourth and little toes. There was no other deformity. There was no hepatosplenomegaly or optic disc change. The blood and urine were normal. The ear drums could not be seen because of narrowing of the external auditory meati. An audiogram showed marked conductive deafness on the right, but on the left there also seemed to be nerve deafness.

Radiographic examination—The whole skeleton was radiographed. There was greatly increased uniform density of all the bones, typical of osteopetrosis. There were no fractures. The large limb bones, ribs and clavicles tended to be a little broader than average but showed normal metaphysial modelling. The pelvis and scapulae were very dense. The vertebrae showed the typical " thick sandwich " appearance of osteopetrosis. The base and vault of the skull (Fig. 12) were dense and thickened throughout, with reduction of the internal

auditory meati and air sinuses and clubbing of the posterior clinoid processes. The facial bones and especially the mandible were both dense and thickened. The hands (Fig. 14) showed cigar-shaped metacarpals from thickening of the cortices of their shafts. A similar appearance was present in the proximal and middle phalanges. In the index fingers the middle phalanges were rudimentary or absent and the distal were bizarrely shaped and angled outwards. In the foot a lesser degree of diaphysial thickening was seen in the metatarsals

FIG. 11
Case 2—Photograph of patient.

FIG. 12
Case 2—Skull.

and in the fifth proximal phalanx. All the middle and distal phalanges were rather short. These were fused in the fifth toe. The distal phalanges of the first and second toes lacked the normal tufting at their tips.

Biochemical and other investigations—The serum calcium was 8·3 milligrams per 100 millilitres, alkaline phosphatase 18·2 and 17·2 (Shinowara) units per 100 millilitres, and inorganic phosphorus 5·7 and 4·1 milligrams per 100 millilitres. Serum carbon dioxide combining power, proteins and urea were normal. Urinary calcium was 10 milligrams a day (single determination).

Clinical examination and skull radiographs of the parents revealed no relevant abnormality. The brother was not available for examination.

DISCUSSION

The association of syndactyly was found in two reports on osteopetrosis in the literature (Falconer and Ryrie 1937, Higinbotham and Alexander 1941). In both it appears to have been regarded as coincidental (Hinkel and Beiler 1955). However, it is very striking that the five cases described in these reports had the other four features unusual in osteopetrosis which are listed above.

Higinbotham and Alexander (1941) described four siblings aged twenty-one to thirty-seven years with generalised osteopetrosis. All had partial syndactylism, mandibular and facial bone enlargement and very thick skull vaults. Consequently they had prominent foreheads, prognathism and some hypertelorism. Three had slight deformities of the distal phalanges of

FIG. 13
Case 2—Photograph of hands, showing syndactyly.

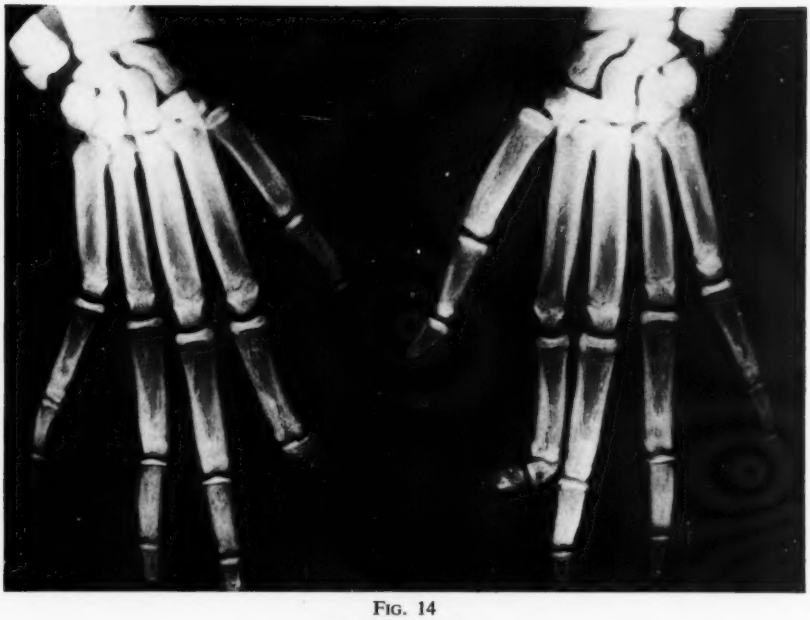

FIG. 14
Case 2—Hands.

one or two fingers (principally the index fingers). The radiographs show diaphysial thickening of all the metacarpals. All four patients had very thick clavicles. Only one had neurological complications (deafness and early optic atrophy) and none had anaemia or fractures. The father denied consanguinity with his wife but she had died. Neither parent had shown the heavy facial appearance of four of their ten children.

Falconer and Ryrie's patient had generalised osteopetrosis. He was a man of thirty-five and from his portrait looks like another member of Higinbotham and Alexander's family. His calvarium was very thick (2–3 centimetres) and the mandible and facial bones were enlarged. He had partial syndactyly and deformity of the distal phalanges of both index fingers. The metacarpals were oblong. The clavicles were thickened and very hard at biopsy. There was deafness and a slight left facial palsy. He had hepatic cirrhosis, a very large spleen and a mild degree of anaemia with 3 per cent reticulocytes. He died shortly after splenectomy. At necropsy all the bones were very dense. Histology showed replacement of cancellous bone by dense ivory-like bone. The parathyroids were normal. It seems probable that the anaemia was caused by cirrhosis or hypersplenism. Although the marrow cavity was somewhat encroached upon by bony thickening the marrow tissue was moderately hyperplastic and not fibrosed. There was no extramedullary haemopoiesis. The parents, who were first cousins, were said to be normal, but one of the four siblings had even more marked thickening of the facial bones, judging from a photograph. She lived too far away to attend for radiographic examination.

Two cases in the literature seem to provide a link between standard osteopetrosis and the variant with syndactyly. Both had generalised osteopetrosis with hypoplasia of all distal phalanges in addition (Seigman and Kilby 1950, Jackson 1951). They did not show syndactyly or thickening of facial bones and metacarpal shafts.

Although thickening of the skull vault, facial bones, mandible and metacarpal shafts is unusual in osteopetrosis (Fairbank 1951, Jackson *et al.* 1954, Hinkel and Beiler 1955), these features can occur without syndactyly or distal phalanx anomalies. This is illustrated by a patient described by Kretzmar and Roberts (1936) who did not have syndactyly (Kretzmar 1957).

Digital abnormalities are recognised in many of the developmental bone diseases. In some, such as Ollier's disease, chondro-osteo-dystrophy, achondroplasia and arachnodactyly they are clearly due to involvement of the digits in the generalised bone disorder. However, in acrocephalo-syndactyly, myositis ossificans progressiva, pseudohypoparathyroidism, Laurence-Moon-Biedl syndrome and several other rare diseases, the digital abnormalities appear as if due to a distinct but associated gene. Syndactylism and hypoplastic distal phalanges in osteopetrosis seem to be another example of the latter group.

CONCLUSION

A minority of cases of osteopetrosis show in addition syndactyly and distal phalangeal anomalies. The seven cases that have been reported with this combination have had an unusual degree of density and thickening of the skull vault, face and mandible, and of the shafts of the metacarpals, metatarsals, proximal phalanges and clavicles. It is submitted that these features constitute a distinct morphological variety of osteopetrosis.

I particularly wish to thank Professor F. Forman for suggestions which stimulated the writing of this article. I am grateful to Dr W. P. U. Jackson, Dr L. Vogelpoel and Dr R. S. Mibashan for valuable advice, to Professor J. F. Brock and Dr M. Horwitz for permission to publish, and to Mr B. Todt for the photographs.

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INTERTROCHANTERIC OSTEOTOMY FOR OSTEOARTHRITIS OF THE HIP

A Review of Fifty-eight Operations

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The name of McMurray (1935, 1939) is firmly associated with intertrochanteric osteotomy for the treatment of osteoarthritis of the hip, although this method was based on the bifurcation operation of Lorenz (1919) and was suggested by several previous authors—Ashley (1923), Galland (1930), Hey Groves (1933) and Lowendorf (1933). There is still, however, no unanimity about the technique of operation and no agreement on its rationale or on the long term results. This paper presents the results in cases of intertrochanteric osteotomy performed for osteoarthritis of the hip at the Royal National Orthopaedic Hospital between the years 1935 and 1955.

CLINICAL MATERIAL

Eighty-seven patients had been treated in this way. Of these, six are known to have died, twenty-four were not traced, and the remaining fifty-seven, roughly two-thirds of the total, were reviewed. One patient had both hips treated, making fifty-eight operations in all. Some of the patients were seen only once at review, but those treated recently were seen several times. Only a few were seen by us before operation.

Sex—Of the fifty-seven patients reviewed, forty were women and seventeen men. As in Gade's (1947) series, the proportion of women was high; this is in keeping with the statement of Lloyd-Roberts (1955) that osteoarthritis of the hip is twice as common in women as in men.

Presumptive cause—In thirty-eight of the fifty-eight hips no cause of the osteoarthritis was evident and it was recorded as idiopathic. The seeming causes of the remainder were: congenital dysplasia, twelve; old Perthes' disease, three; slipped epiphysis, three; protrusio acetabuli, one; old septic arthritis, one. These figures agree closely with those reported by Lloyd-Roberts (1955) in his series of hips operated upon for osteoarthritis.

Bilateral affection—In twenty instances the opposite hip presented osteoarthritis severe enough to cause symptoms; in thirty-eight the opposite hip appeared normal.

Age—The average at operation for all patients was 55·4 years and the range twenty-seven to seventy-two years (Fig. 1). There was little difference in the average age in the different groups.

Methods of fixation—The series has been divided into three groups according to the type of fixation: 1) thirty-three hips treated after operation by external fixation, usually a double plaster spica; 2) eighteen hips treated by osteotomy with internal fixation, usually a modified McKee pin and plate; 3) seven hips treated by combined internal and external fixation.

RESULTS

Duration of observation—The longest duration of observation was eighteen years, and the shortest nine months. The latter was considered to be the shortest period at which any assessment of the result could be made. For patients treated with external fixation alone the average was five years and two months; with internal fixation alone it was thirteen months, varying from twenty-one to nine months. Patients treated by internal fixation were kept under observation for a much shorter time, and this must be remembered in comparing the results. It might be thought, for instance, that after an initial improvement patients would deteriorate after several years. Milch (1947) stated that McMurray's osteotomy could at best be considered

as of only temporary value because it could not modify the underlying arthritic process, and that in time the disability would recur. If this were so, internal fixation would have an unfair advantage in this review. Several authors, however, including Osborne and Fahrni (1950) and Wardle (1955), have shown that the benefits of osteotomy last for many years. Only two of our patients complained of deterioration of the hip operated upon, after a period of relief of symptoms, but complaint of increasing pain and disability in the untreated hip was

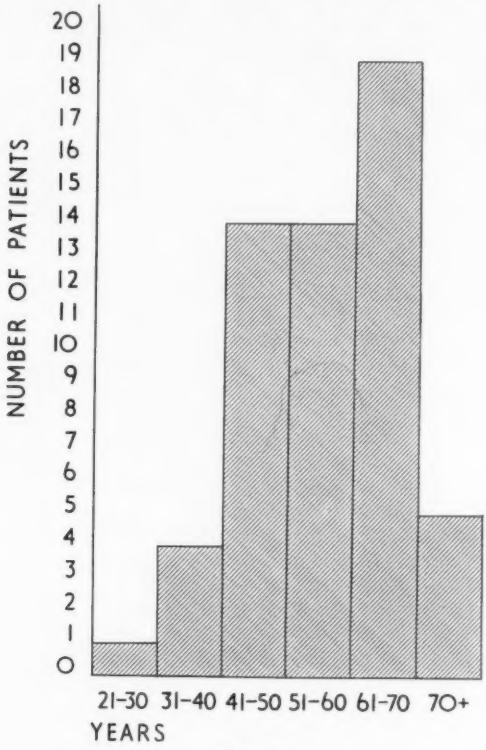

FIG. 1

Age of fifty-seven patients at the time of operation. (Oldest patient was seventy-two; youngest twenty-seven.)

quite common. Though it is clear that the series in which external fixation alone was used and that in which internal fixation was used are not strictly comparable, we believe that a comparison is of value.

Assessment—The patients were assessed according to the table devised by Shepherd (1954) for the study of hip arthroplasty. Since this method takes into account the function of the patient as a whole and not that of the affected hip alone, a poor late result may be due to osteoarthritis in the other hip and not to failure of the operation. Table I shows the analysis of results in accordance with Shepherd's strict criteria, including the assessment of mobility. It will be seen that the number of poor results after external fixation is four times that after internal fixation.

Although a common object of osteotomy is to retain movement in the hip, restoration of movement is not usually expected. The results with exclusion of the mobility index from the calculation have therefore been assessed in Table II. There is now little difference shown between the two techniques.

Complications and causes of failure—A spike formed by the calcar femorale projected from the lower fragment in eight patients; of these, four had excellent or good results, and only one poor. Three patients treated by internal fixation had pulmonary embolism, one patient after osteotomy of each femur and one treated by external fixation; none was fatal. One patient treated by internal fixation developed bilateral phlebothrombosis without embolism.

From the table in which mobility is excluded from the calculations we see that the result was poor in 20 per cent (twelve patients). These patients were reviewed to see whether any common cause could be found for the failure. The reasons were as follows: two falls since

TABLE I

RESULTS INCLUDING MOBILITY

	Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
All cases . . .	14	29	19	38
With external fixation	18	21	15	46
With internal fixation	11	56	22	11

TABLE II

RESULTS EXCLUDING MOBILITY

	Excellent (*per cent*)	Good (*per cent*)	Fair (*per cent*)	Poor (*per cent*)
All cases . . .	33	33	14	20
With external fixation	39	28	12	21
With internal fixation	33	39	17	11

the operation, with a fracture of the femur on each occasion; fracture of the femur, resulting in shortening and a stiff knee; infective arthritis of the hip; spastic paraplegia from thrombosis of the spinal vessels; avascular necrosis of the head of the femur after a transcervical fracture which occurred before the osteotomy; non-union at the osteotomy site; hysterical paresis; antecedent bilateral protrusio acetabuli; homolateral stiff knee and hip (two patients); bony ankylosis of the hip (two patients). With the exceptions noted, these causes appeared after the osteotomy. No single cause, therefore, contributed greatly to these poor results. Ten of these patients with poor results were treated with external fixation.

Pain—Pain was often the only indication for operation, and the results have accordingly been assessed with regard to pain alone in fifty-seven patients. Before operation forty-three patients had pain of the most severe grade (" crippling "), six had " disabling " pain, five " made concessions " to pain, two had pain which they ignored and one had no pain. After operation twenty-six patients had no pain, twenty had a mild ache, seven " made concessions," one had " disabling " pain and three had " crippling " pain. In other words, forty-six out of fifty-seven, after operation, had no pain, or an occasional ache only, while eleven patients had a significant amount of pain. This may be compared with the series of Osborne and Fahrni (1950); of seventy-five patients fourteen had no relief of pain. We agree with Osborne and Fahrni that the relief of pain is long lasting—in our series up to eighteen years after operation. With external fixation only, 78 per cent had pain before operation and 6 per cent after. Of the patients treated with internal fixation alone and observed for a much shorter period, 94 per cent had pain before operation and 6 per cent after.

Patient's assessment—The patients were more easily pleased than the assessment of Shepherd (1954) would suggest; thirty-eight of fifty-eight (66 per cent) were satisfied in every way with the result of the operation; eleven (19 per cent) were satisfied but with some reservation; two (3 per cent) were doubtful; and seven (12 per cent) thought the operation not worth while. **Mobility**—The assessment of movement was difficult. The range of movement at the hip, as recorded by different examiners before operation, showed great variation. Great care was taken at the follow-up examinations in recording movement, but for the range before operation we had in most cases to rely on the case histories. Taking the series as a whole, there appeared to be a slight gain in the range of movement. In patients for whom information was available twenty-six gained movement, five remained unchanged and fourteen lost movement. Of twenty-eight hips treated by external fixation, twelve (43 per cent) gained movement, whereas

FIG. 2

FIG. 3

Radiographs before and after operation in a patient whose post-operative treatment was simply by strapping extension. Note the increase in the joint space, the healing of the cysts and the improvement in the general outline.

fourteen of seventeen (82 per cent) treated by internal fixation alone, gained movement. It may be that internal fixation, which allows early movement of the hip, was superior to external fixation in plaster, but the unequal duration of observation makes fair comparison impossible.

Two patients had been treated after operation by skin traction alone, without immobilisation of the hip. The length of follow-up was eight years and seven years respectively, and in each patient the range of movement had increased greatly. One had made the greatest gain in movement of all the patients in the series, with an increase in the mobility index from 3 to 46·5, and in the other the index had increased from 18 to 46. Considering the degree of stiffness before operation these were two of the best results in the whole series.

In Osborne and Fahrni's series, where external fixation by a plaster spica was employed, there was, taken over all, a slight decrease in flexion movement after operation. Campbell

and Jackson (1955) reported forty-six patients, in whom a simple abduction osteotomy was performed without deliberate medial displacement. Some were treated by internal fixation and some by external fixation. They found that the flexion range was decreased in 40 per cent and increased in 17 per cent. Campbell (1955), reporting later thirty-four patients treated by internal fixation, found that movement was decreased in only 6 per cent and increased in 63 per cent.

Improvement in the radiographic appearances—All patients who showed a significant increase in movement showed also, to a greater or lesser degree, appearances of regression of the osteoarthritis. In four instances an increase in the joint space and more regular joint outlines were seen, although movement appeared to have diminished.

Figures 2 and 3 show the radiographs before operation and at follow-up of the second patient treated by strapping extension, in whom the mobility index increased from 18 to 46. Note the increase in the joint space, the healing of the pseudocysts, and the improvement in the joint outline. In the whole series of fifty-five hips for which radiographs before and after operation were available, thirty-eight showed unmistakable evidence of the changes described, sixteen showed no change or advance of the osteoarthritis, and in one instance there was radiographic deterioration after early improvement. These changes were mentioned by Osborne and Fahrni (1950), who stated that no successful case of osteotomy showed progress of the osteoarthritis. Wardle (1955) also mentioned improvement in the joint space.

Medial displacement—McMurray (1935) in his original description of the operation said that the shaft should be displaced medially so that it lay just below the lower border of the acetabulum: " if this displacement is not sufficient there can at best be only a partial relief of symptoms and a disappointing result." Malkin (1936) showed that simple osteotomy of the femur at or just below the lesser trochanter, with abduction of the lower fragment but no displacement, was able to relieve or abolish pain in the hip in eleven of fourteen patients. McFarland (1954) believed that even when the displacement was not maintained the result might be good. Osborne and Fahrni (1950) showed experimentally on necropsy specimens that the joint pressure was reduced to nil after displacement osteotomy, but were uncertain whether this ever happened clinically. They thought that inadequate displacement gave less lasting relief. They considered that medial displacement should be enough to block all adduction movement, and found that this was so after 95 per cent of successful operations and not so in twelve unsuccessful operations. On the other hand Campbell and Jackson believed that the essentials were to divide the bone and to correct deformity, and they did not deliberately displace the shaft medially. Yet their results compared favourably with those of Osborne and Fahrni.

TABLE III

RELIEF OF PAIN ACCORDING TO THE AMOUNT OF MEDIAL DISPLACEMENT
(Pain graded 1–5 according to Shepherd 1954)

Degree of pain	1	2	3	4	5
Under half diameter	21	16	6	1	2
Over half diameter	5	4	1	0	1

We found it impossible to measure the medial displacement of the lower fragment in relation to the pelvis; the medial displacement has therefore been expressed as a fraction of the diameter of the femur at the level of section. The relief of pain has been correlated with the amount of displacement in Table III.

Of patients with less than half a diameter of displacement 80·4 per cent had no pain, or pain which was ignored, compared with 81 per cent of those with displacement of over

half the diameter. These figures suggest that the amount of medial displacement is not important. In eleven cases the medial displacement was more than half the diameter, in three it was less than a quarter of the diameter, and in the remaining forty-three hips it lay between a quarter and a half the diameter.

Position of the upper fragment—Various writers, including Hoets (1949), Stuck (1949) and Osborne and Fahrni (1950) have ascribed the beneficial results of intertrochanteric osteotomy to contact of the femoral head bearing undamaged articular cartilage with the weight-bearing part of the acetabulum. Whenever possible we measured the relation of the upper fragment to the pelvis before operation, immediately after operation, and in the final radiograph. Only those who had no clinically detectable abduction or adduction movement, before and after operation, were suitable, because movement in this plane would have vitiated the results. It was not possible to measure the changes of position of either flexion or rotation. Under these conditions twenty-six hips were available for measurement. In thirteen of these there was no change of abduction or adduction of the upper fragment, the position of the head in the acetabulum after operation being the same as before. In eight, on the intermediate radiograph, the upper fragment was shown abducted between 7 degrees and 27 degrees as compared with the position before operation, and in each case returned to its previous position. In one patient coxa vara gradually developed, and finally the head fragment was abducted 14 degrees and the shaft adducted. In four instances the head fragment adducted between 8 degrees and 20 degrees and in all four remained in this adducted position. In twenty-one of twenty-six hips (81 per cent) the final position at the hip was the same as before the operation.

FIG. 4
The McKee nail and modified plate to allow for the medial displacement of the distal fragment.

Position at the osteotomy site—The relation of the fragments at the osteotomy site was also measured. Of the twenty-two patients treated by external fixation thirteen remained as they were placed at operation; in nine patients the distal fragment adducted 10 to 30 degrees. In all but one patient of twelve treated by internal fixation the position remained as at operation (Fig. 4). In the one exceptional case a very short nail had been used, and radiographs showed this to have moved as the distal fragment adducted.

Deformity—How successful was the operation in correcting deformity? Unless flexion deformity is severe, no attempt is usually made to correct it, and in fact on clinical examination there was little difference in this deformity before and after operation. The correction of adduction or abduction deformity was measured in forty-two patients and the results are seen in Table IV. The average adduction deformity before operation was 11·5 degrees, and after operation 5 degrees. In this series there was improvement, but the figures are disappointing because nineteen of the forty-two patients still had significant adduction deformity. This is not the whole story, however, for a number of patients were able to correct what would have been an adduction deformity by recovering movement.

Osborne and Fahrni (1950) ascribed the relief of pain to a block to adduction at the neutral position. The results in our series do not support this view. Eight patients had fixed

abduction, ten could not adduct the limb, and in thirty-six some adduction was either fixed or possible. In a comparison of these three groups with the relief of pain obtained in each, no difference was found.

TABLE IV

DEFORMITY

	Adduction				Abduction
	0°	5–10°	11–20°	21–40°	
Before operation	13	10	15	3	1
After operation	20	14	5	0	3

Age—Rather surprisingly there was no variation with age. Excellent or good results were obtained in 65·4 per cent of patients over sixty years of age and in 65·6 per cent of patients under sixty. These results are seen in Table V.

TABLE V

RESULTS ACCORDING TO AGE

Age (*years*)	Excellent	Good	Fair	Poor
Under 60	12	9	4	7
Over 60	7	10	4	5

Knee movement—The significant results in the present series are shown in Table VI. These figures show that with external fixation there were five times as many patients with more than 30 degrees' limitation of flexion compared with those treated by internal fixation. Osborne

TABLE VI

KNEE MOVEMENT AFTER OSTEOTOMY

	Full knee movement	Limited by 30°	Limited by more than 30°
With external fixation	23 (70%)	2 (6%)	8 (24%)
With internal fixation	14 (78%)	3 (17%)	1 (5%)

and Fahrni found that of seventy-five patients all but six regained the range present before operation, within six months. Those patients were treated in plaster. Wardle (1955) in his series of forty, found that the average range of knee movement was 100 degrees.

Backache—Before operation fifteen patients had backache. After operation seven had lost the pain, three had improved and five remained unchanged. No patient, previously free, developed backache after operation.

CONCLUSIONS

1. Intertrochanteric osteotomy is valuable in the treatment of patients with osteoarthritis of the hip, giving a high percentage of satisfactory results. It often relieves the pain immediately, is long-lasting in its effects, and may even increase the range of movement.
2. There is no evidence from our figures that the extent of medial displacement of the lower fragment influences the result as judged from relief of pain, performance, and the patient's assessment. Movement, however, is less improved if displacement exceeds half the diameter of the divided bone.
3. Our observations did not support the view that improvement is caused by a changed relationship between the upper fragment and the acetabulum. When measurements were possible the position of the upper fragment usually remained virtually unaltered.
4. Our figures confirm that in most patients relief of pain is immediate; that is to say, the patient is aware on regaining consciousness that his pain has gone, even though he formerly had pain at rest. Whatever may be the mechanism that relieves the pain, it acts immediately.

We readily acknowledge our thanks to Mr K. I. Nissen, at whose suggestion this investigation was undertaken, and to Mr H. Jackson Burrows for their advice, encouragement and help in preparing the paper, and to the Consultant Staff of the Royal National Orthopaedic Hospital who allowed us to examine their patients. We should like also to record our appreciation of the ready aid of the Medical Records Department of the Royal National Orthopaedic Hospital and the Department of Medical Photography of the Institute of Orthopaedics.

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STRESS FRACTURES OF THE TIBIA IN ATHLETES OR "SHIN SORENESS"

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"Shin soreness," "shin splints" (and "Charlie Horse" on the Western side of the Atlantic) are terms used by athletes to describe a painful condition of the shin which can seriously interfere with training and performance in the various forms of running.

The symptoms start insidiously: at first the athlete feels a dull gnawing pain in one or other shin, which occurs towards the end of a run. The intensity of the pain, at first mild, gradually increases over the days, and will ultimately become so severe that running or sprinting cannot be continued.

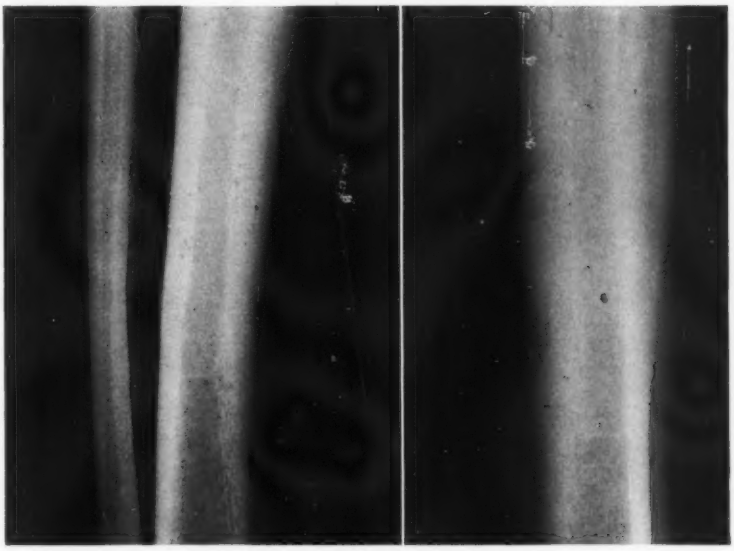

FIG. 1

A typical stress fracture of the tibia in "shin soreness." Two months after the onset of symptoms a periosteal reaction is visible in the antero-posterior view; in the lateral view the fracture line can be seen passing up through one cortex only.

At first the pain passes off with rest, but recurs with further running. Over the days shorter and shorter distances produce the pain, which persists for some hours after athletic activity has ceased. Finally the pain continues during the night, but does not prevent sleep, and any attempt at running causes severe pain at once and training has to be discontinued.

With a few days' rest from sport the athlete feels better and tries to run again, only to find that the pain recurs; in this way a whole season of training is spoilt.

The purpose of this paper is to show that "shin soreness" is caused by a particular type of stress fracture of the tibia which is difficult to diagnose because it is an incomplete fracture involving only one cortex of the bone, and is not apparent in the radiographs until a later stage (Fig. 1).

TABLE I

DETAILS OF SIXTEEN PATIENTS WITH STRESS FRACTURES OF THE TIBIA CAUSING "SHIN SORENESS"

Case number	Sex	Age (*years*)	Length of history	Sport	Time off sport
1	M	15	5 weeks	Running	4 months
2	F	16	Unknown	School sports	Well after biopsy
3	M	18	Many weeks	School sports	5 months
4	M	20	5 weeks	Running	4 months
5	M	19	2 months	Running	3½ months
6	M	21	2 months	Athletics	2 months
7	M	27	3 months	Running	Unknown
8	F	20	3 weeks	Running	3 months
9	M	23	(L) 4 weeks (R) 4 weeks	Running	1 month Unknown
10	M	15	"Some weeks"	Running	More than 3 months
11	M	17	3 weeks	Running	More than 4 months
12	M	19	Unknown	Running	More than 3 months
13	M	18	3 weeks	Running	More than 3 months
14	M	23	2 months	Running	2 months
15	M	17	Unknown	Running	3 months
16	F	19	5 months	Ballet	Unknown

TABLE II

STRESS FRACTURES OF THE TIBIA RECORDED FROM 1938 ONWARDS

Age and type of patient	Athletes	Recruits	Other	Total
Children 4–16 years	2	—	20	22
Adults 16–28 years	2	26	18	46
Ballet dancers 20–26 years	—	—	5	5
Adults 28–44 years	—	—	—	0
Adults 44–68 years	—	—	5	5
			Total	78

(From Hansson 1938, Roberts and Vogt 1939, Weaver and Francisco 1940, Nordentoft 1940, Pfahler 1941, Hartley 1942, Krause and Thompson 1943, Robin and Thompson 1944; Proctor, Campbell and Dobelle 1944; Wolfe and Robertson 1945, Mann 1945, Leveton 1946, Kelly and Murphy 1951, Singer and Maudsley 1954, and Burrows 1956.)

FIG. 2 FIG. 3

Case 6. Figure 2—Two months after the onset of " shin soreness " the radiographs of a twenty-one-year-old athlete showed a faint haze of periosteal new bone on the medial side of the tibia, which is barely visible in this reproduction. Figure 3—The same athlete as in Figure 2. After a further month the new bone formation is obvious, but no fracture line is visible.

CLINICAL MATERIAL

This study is based on a considerable number of patients with " shin soreness " seen at the Middlesex Hospital Athletic Clinic and elsewhere, in sixteen of whom there was definite radiological confirmation of the diagnosis of stress fracture.

It must be emphasised that radiological changes are almost invariably a late manifestation, and they are not seen in many cases of " shin soreness " which are typical in all other respects but have been diagnosed and treated early.

Table I gives details of the cases with radiological changes. For comparison, Table II summarises seventy-eight stress fractures of the tibia recorded in the literature since 1938. Of the twenty-six recruits included in this Table only three are said to have developed their symptoms while running.

SYMPTOMS AND SIGNS

A typical example of shin soreness is shown in Case 6 in Table I. The patient was a man aged twenty-one who worked as a clerk in an office; in the evenings and at weekends he trained as a middle-distance runner.

FIG. 4

Case 6—Three weeks after the previous radiograph (Fig. 3) the fracture line is visible. It is nearly four months since the onset of symptoms.

For two months before being seen he noticed a little pain in the lower right shin towards the end of a run, which gradually got worse until the day before attending hospital, when it became severe.

Examination showed a healthy young man, who complained of pain in the antero-medial part of the right shin. This area was very tender and slightly oedematous. A radiograph showed a slight haze of periosteal new bone (Fig. 2).

Elastic adhesive strapping was applied to the leg from the toes to below the knee, and the patient was instructed to rest from all sport but to continue with his office work. A month later there was considerably more new bone formation (Fig. 3). Pain was still present on activity but not at rest. A below-knee walking plaster was applied.

Three weeks later the plaster was removed and radiographs then demonstrated clearly a fracture running upwards and inwards in the postero-medial cortex of the lowermost third of the tibia (Fig. 4). The pain and tenderness had gone and the patient was allowed to begin training again. After a further six weeks there were no symptoms despite full activity, and the only physical sign was some thickening of the tibia at the site of fracture (Fig. 5).

Table I shows that most of the patients were in their late 'teens or early twenties, three being school children. Among the younger patients, a girl aged sixteen who was doing much running in school sports began to complain of pain in the shin, about the centre (Case 2, Table I). Radiographs showed new bone formation, and the possibility of a neoplasm was considered. A biopsy was performed, and histological preparations were reported to

FIG. 5

Case 6—The final healing of a " shin soreness " stress fracture, illustrated in the preceding figures. Only the postero-medial cortex of the tibia was involved. This type of fracture is always incomplete.

show a chronic inflammatory lesion. The fracture united quickly after operation and there were no further symptoms (Fig. 6). This case is unusual in that the lesion was in the centre of the shaft of the tibia anteriorly, whereas the most common site is near or at the

TABLE III

SITE OF SEVENTEEN STRESS FRACTURES

Type of lesion	Level in tibia		
	Lowermost third	Middle third	Uppermost third
Complete crack in one cortex	9	1	1
Periosteal reaction only .	5	1	—
Total	14	2	1

junction of the middle and lowermost thirds postero-medially. Table III shows the site of the seventeen fractures under consideration, and Table IV gives the level of those fractures summarised in Table II.

FIG. 6

Case 2—A girl who did much running in school sports developed pain and swelling of the shin. The early radiograph (*left*) showed subperiosteal new bone formation. A month later the bone formation was considerably more marked (*right*). This site is more typical of the ballet dancer's fracture, being anterior and in the middle of the shaft of the tibia.

The fractures occurring in athletes are concentrated in the lower part of the tibia and in recruits in the uppermost third. In the series of stress fractures in ballet dancers recorded by Burrows (1956) all the fractures were in the middle third of the tibia (as was the stress

TABLE IV

SITE OF STRESS FRACTURES OF THE TIBIA IN SEVENTY-EIGHT PATIENTS REPORTED IN THE LITERATURE

	Level in tibia		
	Lowermost third	Middle third	Uppermost third
Number of fractures . . .	6	7	65

fracture in a ballet dancer included in this series). The stress fractures of middle age occur in the lowermost third of the tibia and, in common with the type seen in recruits, involve both cortices of the tibia.

DIAGNOSIS

Diagnosis is difficult because many patients seen early and treated by rest recover without radiological changes sufficient to confirm the diagnosis.

There is usually a history of pain becoming more severe during several months. At first it is felt only at the end of a run, but it gradually comes on earlier and earlier. There is never a history of an injury immediately before the onset, or even of a sudden onset of pain. The pain is generally felt in the front and lower part of the leg.

Examination in an early case will elicit tenderness of the shin, usually the medial border, but not necessarily exactly where the pain is felt. A little oedema may be present early, and at a later stage there is a definite thickening of the subcutaneous surface of the tibia. Sometimes the swelling can be seen (Figs. 7 and 8).

It is possible to reproduce the pain in some patients by " springing " the tibia. This has to be done by straining the tibia against a fulcrum (such as the knee of the surgeon) placed against the outer side of the leg at the level of tenderness; when the leg, held at the knee and the ankle, is pressed on to this fulcrum a fracture through the medial cortex of the tibia is opened and pain occurs.

FIG. 7

In this patient the swelling of the shin is seen and photographed only because the site is on the crest of the tibia. Usually the swelling is on the antero-medial surface of the tibia and is difficult to see and photograph. The patient illustrated was a ballet dancer.

Radiological appearances—This type of stress fracture differs from the more common uppermost third fracture that occurs in recruits and the lowermost third fracture of the middle aged described by Singer and Maudsley (1954). Most stress fractures of the tibia previously recorded show as a transverse lesion across part or whole of the shaft of the tibia. In the earliest stage there may be only a slight loss in the density of the bone (Figs. 9 and 10). Later the bone immediately around this area becomes dense, and outside the cortex a little fluffy new bone can be seen which later condenses to form a hard thickened prominence. In the " shin soreness " type the fracture appears to disrupt the periosteum over a varying distance, but at first there is little or no disturbance of the cortical bone. Later a faint haze of subperiosteal new bone can be seen, and this thickens and spreads until finally a linear fracture is visible in the cortex, only one side of the bone being involved.

The line of fracture usually runs upwards and inwards from the postero-medial cortex. The direction is not, however, as constant as the comparable stress fracture of the fibula in athletes. Oblique views will often show new bone formation before any fracture line is visible (Fig. 11).

Sometimes the radiographs do not show the fracture until nearly three months after the onset of symptoms, despite repeated examinations (Fig. 12). Table III separates the patients in whom the only radiological change was the formation of a smaller or longer amount of new subperiosteal bone from those with a definite crack.

MECHANISM OF THE FRACTURE

The direction of the line of fracture suggests that usually a strain has been applied in such a direction as to open the postero-medial surface of the tibia at its lower end, and sometimes

the postero-lateral surface. In one instance the upper postero-medial border of the tibia was affected and the fracture line was directed downwards and outwards (Fig. 13).

It is possible that the strong calf muscles which arise from the middle and upper part of the back of the shaft of the tibia may, when used at their greatest strength, cause the tibia to bend slightly in such a way that it bows forwards. It has been shown by Devas and Sweetnam (1956) that strong muscular activity can draw the fibula towards the tibia, and this is perhaps

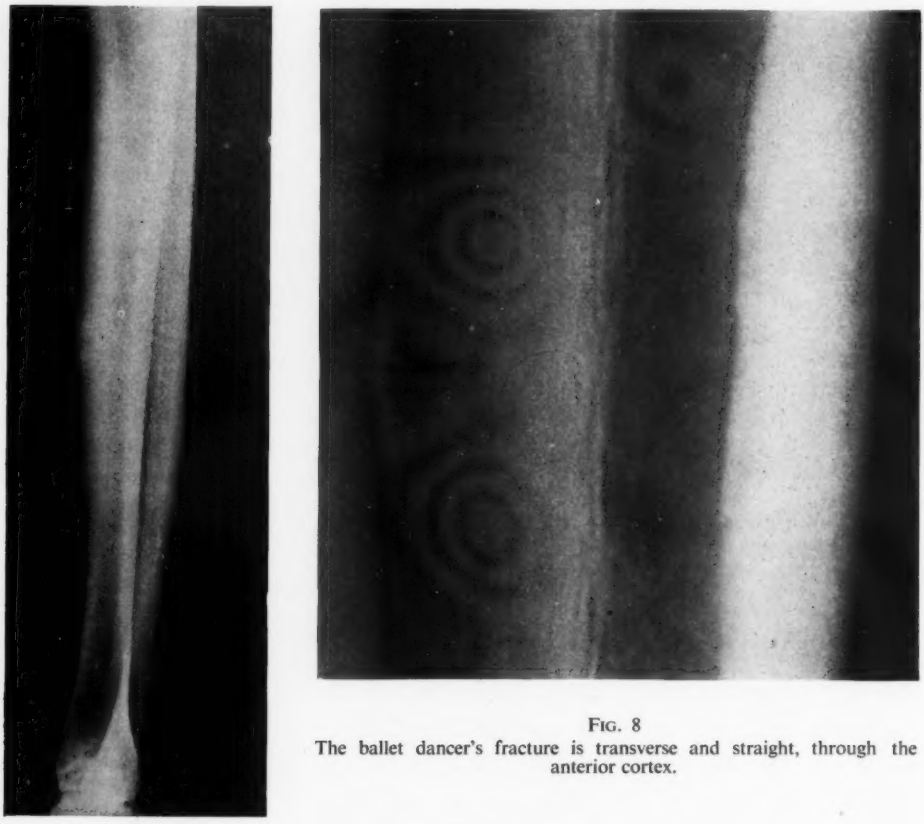

FIG. 8
The ballet dancer's fracture is transverse and straight, through the anterior cortex.

the cause of stress fractures of the fibula in athletes. These two types of fracture occur in the same type of individual, and it seems likely that the same mechanism is responsible for the tibial fracture also (Figs. 14 and 15).

TREATMENT

Rest is all-important and probably the only essential part of treatment. By rest is meant abstention from running and all activity that causes symptoms.

Elastic adhesive strapping applied from the toes to below the knee appears to help; the patient is usually able to follow a sedentary occupation. In patients who continue to have symptoms with ordinary daily activities a below-knee walking plaster will allow them to keep about.

Physiotherapy does not help until the fracture has united, and hydrocortisone injected into the fracture site in one patient had no success.

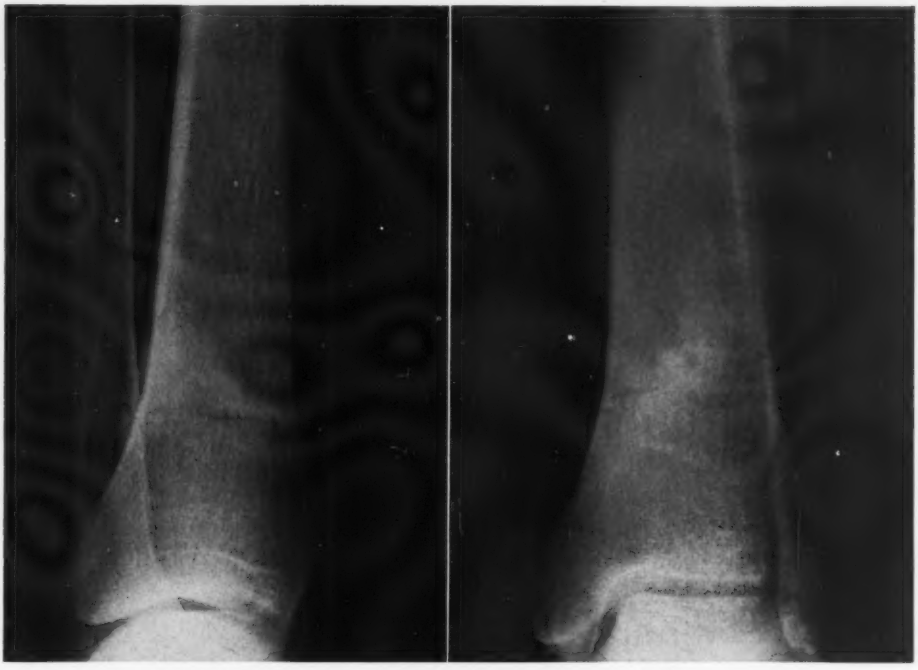

FIG. 9

The early stages of a stress fracture in the lowest third of the tibia in a middle-aged man.

FIG. 10

Two months later healing is taking place. The fracture is transverse and involves both cortices of the tibia.

When there is no longer any pain or tenderness at the fracture site the patient is allowed to start gentle training, which is gradually increased to full training over four to six weeks, provided there are no further symptoms.

DISCUSSION

A fracture of the type described has been reported by others on five occasions (Weaver and Francisco 1940, Pfahler 1941, Krause and Thompson 1943, Wolfe and Robertson 1945, and Kelly and Murphy 1951) but the association with " shin soreness " does not appear to have been recognised previously. The text-books and papers on athletic injuries ascribe shin soreness to strains of muscles and such like conditions (Lloyd, Deaver and Eastwood 1936; Symposium on Athletic Injuries, Medical Press and Circular 1937; Thorndike 1948, Tucker 1950, Knight 1952, Woodard 1954, and Fletcher 1956).

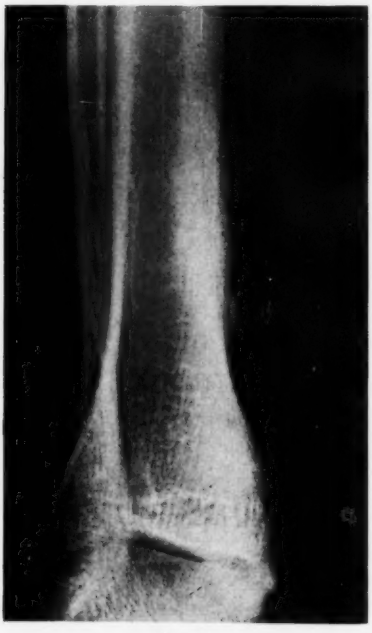

FIG. 11

FIG. 12

Figure 11—An oblique view showing the periosteal new bone formation on the postero-medial border of the lowest third of the tibia. Figure 12—This patient, a middle-distance runner, had typical " shin soreness " but the only radiological change observed was a little periosteal new bone formation towards the back of the tibial shaft.

Stress fractures of the tibia have been known for many years, particularly in recruits; indeed, Aleman in 1929 noted that there were reported one hundred cases of so-called " periostitis tibiae ab excercito " each year in the Swedish army, but he considered the condition an " insufficiency fracture."

Since then many reports on stress fractures of the tibia have appeared, but it was not until shortly before the second world war that the condition began to be recognised for what it is. Even more recently material from biopsy performed in two reported cases (Roberts and Vogt 1939, Weaver and Francisco 1940) was thought to show a form of chronic inflammation and this would be misleading unless the clinical picture is understood, because both the histological and the radiological appearances of stress fractures do not differ greatly from those of a low-grade inflammatory process.

One of the patients in this series was subjected to biopsy and the pathological report was that of chronic inflammation, but the histological section was not available for study.

It seems likely that the five ballet dancers recorded by Burrows (1956) in great detail had injuries of a similar nature, for the symptoms, signs and progress appear to have followed a comparable course to that of shin soreness, although the site and radiological appearance

FIG. 13

A girl aged twenty had the typical signs and symptoms of " shin soreness " except that the site was in the uppermost third of the tibia. The fracture line runs downwards and inwards but is only through one cortex. There is some evidence from the radiographs and the history that there has been a previous stress fracture in the lowest third of the same tibia.

of the lesion suggests a different mechanism. The case recorded in this series was seen before Burrows's description was published, and at that time was considered to be an atypical " shin soreness " type of stress fracture.

The interesting feature about this fracture in athletes is that it is incomplete, involving only one cortex of the tibia. Other forms of stress fracture of the tibia have gone on not only

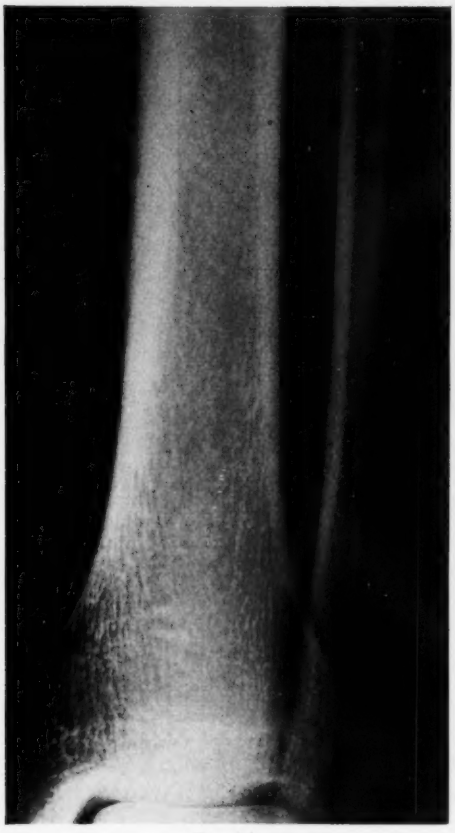

FIG. 14

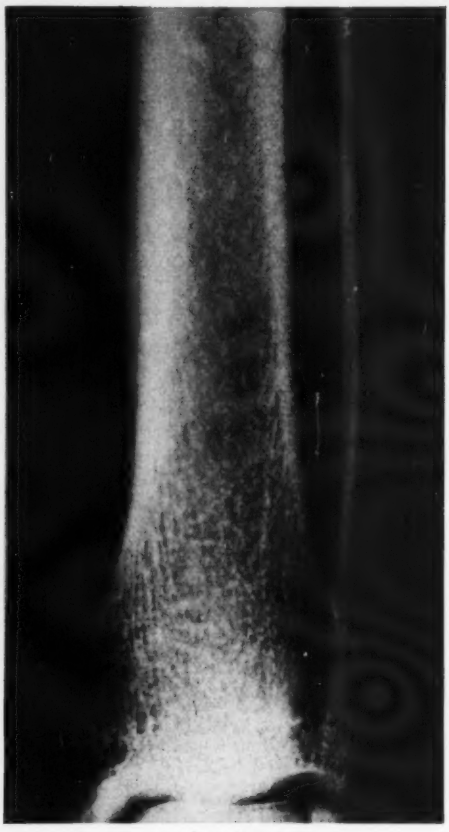

FIG. 15

Figure 14—Five weeks after the onset of symptoms in this athlete a typical haze of new bone is seen on the medial cortex of the tibia. Figure 15—Five weeks later this is more obvious. The previous season this patient had a stress fracture of the fibula.

to involve both cortices but on occasions have developed into complete fractures; one such case was mentioned by Burrows (1956) in a ballet dancer, and others were reported by Roberts and Vogt (1939), Hartley (1942), Krause and Thompson (1943) and Leveton (1946).

A close similarity exists between stress fractures in athletes that occur in the tibia and those seen in the fibula. This similarity is also seen in the stress fractures of middle-aged people, the series reported in the lowest third of the tibia by Singer and Maudsley (1954) being comparable to those seen in the lowest third of the fibula to which Burrows first drew attention in 1940.

A form of chronic anterior tibial syndrome has been suggested by Mavor (1956). The symptoms and signs appear to be very like those of shin soreness, and differentiation might be difficult in the early stages before radiological changes had occurred.

In treatment, absolute immobilisation is probably not necessary provided the forces sufficient to strain the fracture are eliminated; elastic adhesive strapping is sufficient in most cases, but great emphasis must be placed on rest from sport and other activities causing pain at the fracture site. Provided the diagnosis is made early the athlete may well be able to resume training within a few months; but when advice is neglected until late, or the condition is not recognised and sport allowed to continue, many months of disability may ensue.

SUMMARY

1. A type of stress fracture of the tibia in runners is described.
2. This type of fracture, associated with " shin soreness," has not been recognised before.
3. The signs, symptoms and radiological appearances are discussed, and treatment is outlined.

It is a pleasure to thank my former chiefs, Mr Philip Wiles and Mr Philip Newman, for their kindness in allowing me to use their patients for this study; and I am also most grateful to Mr Wiles for his help and advice in the preparation of this report. It is also a pleasure to thank the staff of the Radiological Department of the Middlesex Hospital for their co-operation and assistance.

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THE BALL AND SOCKET ANKLE JOINT—A CONGENITAL ABNORMALITY

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The purpose of this paper is to draw attention to an abnormal type of ankle joint which may be found in association with certain congenital abnormalities of the leg and foot.

Five patients demonstrating this abnormality have been seen in recent years. The first was a boy of ten who complained of pain in his ankle. Radiographs (Figs. 1 and 2) showed an area of osteochondritis dissecans on the upper surface of the talus. The abnormal type of ankle joint was noted, and a radiograph of the foot (Fig. 3) showed fusion of the talus, calcaneum and navicular into one bone. Fusion of the bases of the fourth and fifth metatarsals was also seen.

The second patient, a boy aged fifteen years, complained of weakness of both ankles with recurring sprains. Radiographs showed congenital fusion of talus, calcaneum and navicular. Despite this, definite inversion and eversion movement was present, and could

FIG. 1

FIG. 2

Case 1—Boy aged ten years. Figure 1—Antero-posterior radiograph of ankle. Note area of osteochondritis dissecans on the upper surface of the talus. Figure 2—The same ankle after healing of the osteochondritis.

only be taking place at the ankle joint. The amount of inversion was excessive and accounted for his instability. Figures 4 and 5 show the radiographic appearance of the ankles and feet. On the right side a small area of erosion on the medial side of the talus may also be evidence of osteochondritis dissecans.

Three other examples of this type of ankle joint were found in association with congenital shortening of the lower limb. The fibula was present in all, but in two the lateral malleolus was poorly developed and extended only to the level of the ankle joint. There was absence

FIG. 3

Case 1—Radiographs of foot showing fusion of talus, calcaneum and navicular bone, and fusion of the proximal halves of the fourth and fifth metatarsals.

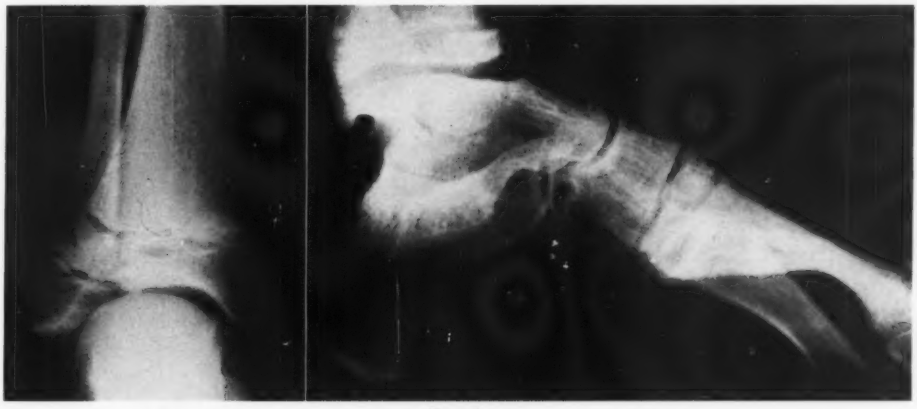

FIG. 4

FIG. 5

Case 2—Boy aged fifteen years. Figure 4—Radiographs of right ankle and foot. Figure 5—Left ankle and foot.

of the fifth toe, fifth metatarsal, and the lateral cuneiform, with a talo-calcaneo-navicular fusion (Figs. 6 and 7). In Figure 6 the normal ankle on the other leg is shown for comparison, and the relative lengths of the two limbs.

FIG. 6

FIG. 7

Case 3—Girl aged thirteen years. Figure 6—Radiographs of the affected and of the normal ankle for comparison. Note the shortening, which measured one and a half inches. Figure 7—Lateral radiograph of the affected foot, showing talo-calcaneo-navicular fusion.

DISCUSSION

I have not found reference to this abnormal type of ankle joint. That it is uncommon is unlikely, because at least five cases have been seen in this area alone in the past seven years.

The abnormal shape of the articulation and its excessive range of movement suggest that the name " ball and socket ankle joint " is apt.

The reason for the development of this type of joint seemed obvious in the first four examples, in which congenital bony fusion of the tarsus precluded normal subtalar and midtarsal movements. The ankle thus allowed its normal flexion and extension, and also

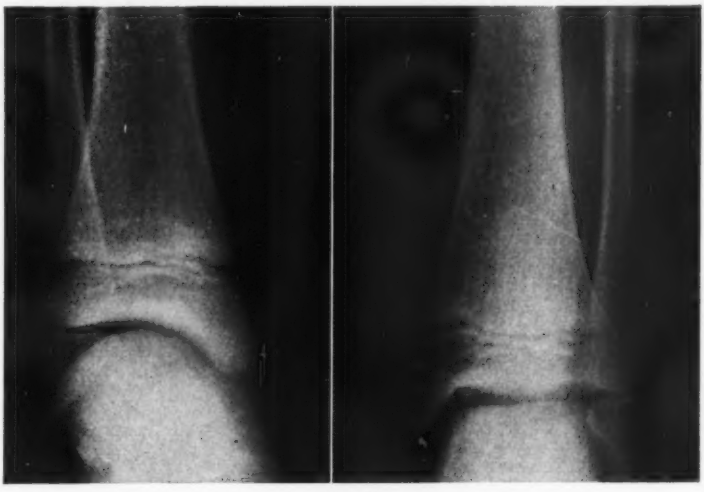

FIG. 8

Case 5—Boy aged fourteen years. Radiographs showing both ankles for comparison. Shortening measured just over one inch. In this case there was no tarsal fusion.

inversion and eversion. In the fifth, and most recent, case the condition was found in a congenitally short limb but without tarsal fusion, and the reason for its presence remains obscure (Fig. 8).

It seems probable that this type of ankle joint may be a not uncommon component of the congenital short leg. In the three examples shown here it was not responsible for symptoms. In the two other cases the legs were of equal length, but there were identical bony fusions in the foot. Both these patients presented with symptoms that can be attributed to the excessive unnatural range of ankle movement.

Since the first of these patients was seen I have looked for an example of this deformity of the ankle after operative fusion of the midtarsal and subtalar joints at an early age, but have been unable to find one.

I am indebted to Professor Sir Walter Mercer for his encouragement in the preparation of this paper, and to Mr R. I. Stirling and Mr W. V. Anderson for their help and permission to report these cases.

FUNNEL CHEST

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From the Eastern Regional Orthopaedic Service, Bridge of Earn Hospital

A not uncommon cause of defective posture in children is a funnel chest deformity. This is usually accepted as being incapable of correction and the child is treated by remedial exercises in the hope of improving the posture, without treating the cause. The purpose of this paper is to demonstrate the striking improvement that can be obtained by operative correction of the chest deformity.

ETIOLOGY

The first description of funnel chest in medical literature appears to have been by Bauhinus in 1596 (quoted by Brown 1940). Since then there have been a considerable number of references, and the literature on the subject was reviewed by Ochsner and DeBakey when they reported a case in 1939. The etiology of the condition remained uncertain until Brown (1939) suggested that the cause was a mechanical one due to a congenital shortening of the central tendon of the diaphragm. This theory does not explain the variations of chest deformity that may occur. Brodkin (1953) pointed out that the anterior part of the diaphragm arises from the embryonic septum transversum and that failure of normal development would produce a relative weakness of this part. Contraction of the more powerful surrounding muscle will then overcome the defective part, drawing it and its lower sternal attachment backwards. Chin (1957) supported this supposition by muscle biopsies taken from the anterior diaphragm during operations for funnel chest deformity. He found marked deficiency of muscle fibres in these cases. It seems probable that this relative deficiency of the muscular element is the cause of the deformity. When the diaphragm is relaxed in expiration it assumes a dome shape. When it contracts to produce inspiration this dome tends to flatten out and increase the internal capacity of the chest. The defective anterior part is overcome by the stronger musculature of the remaining diaphragm which draws the xiphoid and lower sternum towards the vertebral column. This action is seen very clearly when the patient is asked to inspire deeply. As the child grows, the sternum and xiphoid develop a fixed funnel-shaped deformity with the apex of the funnel at the sterno-xiphoid junction. In severe cases the xiphoid and lower sternum may be nearly touching the vertebral column (Fig. 1). At the same time the lower costal cartilages become drawn together and angled backwards.

FIG. 1

Radiograph of a boy of fourteen years, showing gross depression of the sternum, which is only a few centimetres from the thoracic spine. Note the flattening of the chest and lower thoracic spine. (Same boy as shown in Figures 5 and 6.)

The abdominal linea alba is attached at its upper end to the back of the xiphoid and continues upwards under the sternum as the retrosternal ligament. The backwards angulation of the sternum causes relative shortening of this ligament, pulling the chest down and producing an upper thoracic kyphosis.

Many patients give a familial history. Among those recorded here are two sisters, two cousins, and another child whose uncle, now an adult, is severely disabled by the condition. There seems no doubt that the deformity is inherited and occurs in certain families. It is probably much commoner than is generally thought.

FIG. 2

FIG. 3

Figure 2—Boy aged eleven years with progressive deformity. Funnel-shaped depression is accentuated by deep inspiration. This boy also shows lateral indrawing of the lower chest and flaring of the lower costal margins from pull of the defective diaphragm. Figure 3—Same boy showing effect on posture. The shoulders and upper thoracic spine and neck are pulled forwards. The lower thoracic spine is flat.

EFFECTS OF THE DEFORMITY

The deformity is often first noticed soon after birth, but in many individuals it may not become obvious until later childhood or adolescence. At this later stage alterations in the thoracic cage have occurred and the secondary changes in posture have developed. There is a characteristic depression of the sternum which is increased with inspiration. The costal cartilages attached to the lower sternum and xiphoid become angled backwards. The whole chest is flattened and the abdomen is often protuberant in contrast. There is an upper thoracic kyphosis, with the neck and shoulders pulled forward, and a flattening of the lower thoracic spine (Figs. 2 and 3).

In severe cases the thoracic viscera may be affected by the compression and distortion of the chest, and interference with respiration and cardiac function is not uncommon. Most of the patients reported here stated that they were unable to run as far as others of their age because of breathlessness, and this interfered with games and sports. The effect upon respiratory function is seldom disabling, but the effect upon cardiac function may be serious

in more severe cases. The heart is usually displaced to the left as the sternum retracts into the mediastinum. Cardiac arhythmia, a low cardiac tolerance and systolic murmurs have all been reported (Lester 1950*a* and *b*, Ravitch 1951). Electro-cardiographic changes may be found. All the patients in this series have had electro-cardiographic examination carried out, but no abnormality of cardiac function has been noted. Nevertheless, it is interesting that all the children stated that they did not realise how much they were handicapped physically until they appreciated the improvement obtained after operation.

The deformity has a marked psychological effect. These children are usually very aware of the fact that they are different from others. They are shy, retiring and rather lonely, and take little share in the games and activities of their schoolfellows. They try to escape from such recreations as swimming and gymnastics at school, mainly because of self-conscious embarrassment rather than the physical handicap. The parents are worried about their development and find them difficult to manage at home. With the onset of physical maturity the psychological effects become more marked.

TREATMENT

A number of children with this deformity have been seen by the staff of the Children's Orthopaedic Service of this Region. Treatment was concentrated on the postural defects with the usual forms of physiotherapy. The results of such treatment in the more severe cases have been far from satisfactory. Most of them have shown progressive postural deterioration as they grew older. It was the failure to improve these children that led to operative correction of the cause.

The indications for operation are orthopaedic, physiological and psychological. The progressive postural deterioration does not respond to conservative treatment, but improvement after operation is often dramatic. Dyspnoea, diminished exercise tolerance and cardiac arhythmia are also indications for operation, and post-operative improvement in exercise tolerance has been a feature of all our cases. Perhaps the most striking result has been the psychological change. This alone would justify the operation.

The age at which treatment is undertaken will depend upon the severity of the deformity: ideally it should take place before permanent thoracic and postural changes have occurred. At this early stage the operation is simple, but when structural changes in the chest have developed it is necessarily more extensive. The youngest child in this series was a boy aged five who was beginning to show a fixed deformity in the sternum and costal cartilages. There appears to be no reason why the operation should not be done at a younger age; but it is not always possible to predict which children will develop progressive deterioration as they grow older. By the time growth has ceased the thoracic and postural changes are permanent and full correction will not be possible even with an extensive operative procedure. The indication for operation in the late adolescent or adult will, therefore, be mainly to relieve disabling cardiac symptoms.

Technique of operation—The operation is based on the underlying pathology of a mechanical defect in the diaphragm attached to the back of the xiphoid and the adjacent sixth and seventh costal cartilages. The xiphoid and the strong retrosternal ligament must be divided from the sternum. In young children, before fixed changes have occurred or with minimal sternal deformity, this is all that is necessary.

In older children, with structural changes of the thorax, a more extensive procedure is required. Under intratracheal anaesthesia a midline incision is made from above the site of sternal angulation to below the xiphoid. The pectoral muscles are dissected from their attachments to the sternum and costal cartilages and reflected to expose the full extent of the cartilages. The recti abdominis muscles are detached from the lower cartilages. The seventh and eighth cartilages are usually crowded together, and to obtain an adequate exposure of the xiphoid they should first be resected as far down as their point of angulation. The

junction between the xiphoid and the sternum is now defined and the xiphoid is detached by a diathermy knife or a strong pair of scissors. The retrosternal ligament is firmly attached to the back of the ziphoid and is usually divided at the same time. The xiphoid retracts and the lower mediastinum and pericardium are exposed. The fourth, fifth and sixth costal cartilages on each side are resected. It is essential in doing this to remove the cartilages to beyond the point where they angle backwards. In this series the costal cartilages were removed subperichondrially. This makes the procedure more tedious, but it diminishes the risk of opening the pleura, and hardening of the chest wall occurs sooner after the operation. The backward angulation of the sternum is usually between the third and fourth cartilages. At the point where the angulation occurs, a transverse V-shaped osteotomy is performed (Fig. 4). This is easily done with a gouge. The posterior cortex is left intact. A finger is now passed behind the sternum and its posterior aspect is gently cleared of mediastinal attachments.

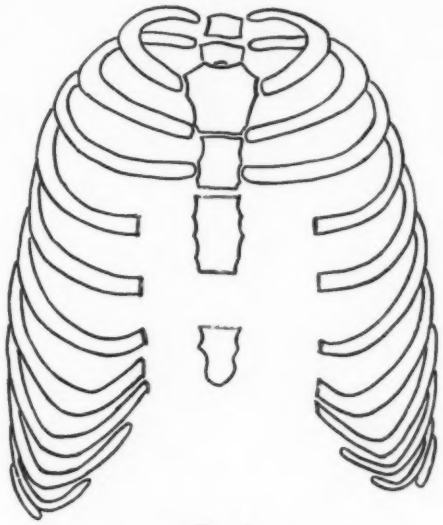

FIG. 4
Diagram of thoracic cage to show the detachment of xiphoid, removal of costal cartilages, and site of osteotomy in sternum.

Provided the retrosternal ligament is not reflected this procedure presents no difficulties. With the finger in the mediastinum, the sternum is elevated forwards. The posterior cortex fractures either completely or in the manner of a greenstick fracture. The wedge osteotomy is thus closed. The elevation of the sternum should be sufficient to allow over-correction because there is always a little loss of correction during healing. A strong curved needle with silk sutures is passed through the periosteum and bone of the anterior cortex to hold the sternum in its over-corrected position. Two mattress-type sutures are usually adequate. The pectoral muscles are reattached. The edges of the upper recti are sutured together to cover the mediastinum and the retracted xiphoid. The skin wound is closed with interrupted sutures. A light gauze dressing is held in place with strapping across the front of the chest.

This operation differs somewhat from those described by others in the literature. In the methods described by Brown (1939) and by Lester (1946, 1950*a* and *b*) wires are passed through the sternum and out through the skin on each side of the wound and attached to a wire ladder across the front of the chest to hold the sternum in the corrected position. Sweet (1944)

modified this procedure by stitching the divided ends of the costal cartilages to the sternum. Ravitch (1949) isolated the sternum from all its attachments and held it in position by sutures at the site of osteotomy: this would surely lead to avascular necrosis.

It seems wiser to avoid any form of external traction because the risk of infection is unjustified in an operation of this nature. It is not necessary to isolate the sternum from its lateral attachments.

Post-operative treatment—As soon as the patient recovers from the anaesthetic he is propped up on pillows and deep breathing is encouraged. It is surprising how fit these children are on the day after operation, and their subsequent progress has given no cause for anxiety. Most of them are anxious to get up on the third or fourth day. Breathing exercises are continued twice a day. The wound is healed in ten days and the patient then begins active shoulder and pectoral exercises, and a few days later is ready for more extensive postural training. The sternum and front of the chest are quite firm at the end of two weeks. From this time the patient should attend the physiotherapy department, being allowed home at the end of three weeks. Regular postural exercises must be continued indefinitely to correct the kyphosis and other postural defects, and to maintain the correction obtained.

RESULTS

This operation has been performed on twelve children varying in age from five to fourteen. In the five-year-old boy, who had early but progressive changes in the sternum and costal cartilages, the simple operation to detach the xiphoid from the sternum was all that was

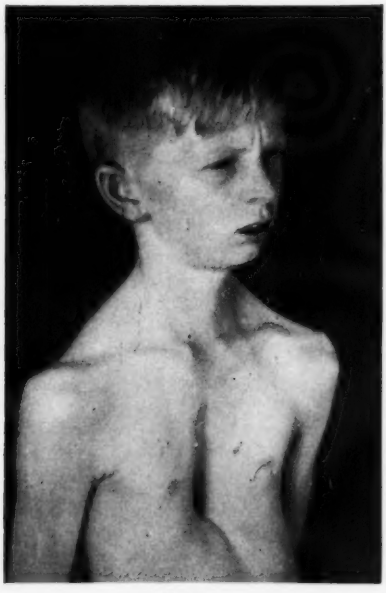

FIG. 5

FIG. 6

Figure 5—Boy aged fourteen years with severe funnel chest, marked flattening of chest, and postural changes. Figure 6—Same boy six months after operation. There is still a little depression of the sternum but posture is greatly improved.

done. In the twelve months that have elapsed since operation the deformity has decreased and the child's posture and general health and development have improved greatly. The remaining eleven patients have been observed for periods ranging between six months and

FIG. 7

FIG. 8

Figure 7—Same boy as in Figure 2, showing correction of chest deformity. Figure 8—same boy as in Figure 2, showing improvement in posture after operation.

FIG. 9

FIG. 10

Figure 9—Girl aged fourteen years with chest deformity and poor posture, and marked psychological effects. Figure 10—Same girl six months after operation. Chest deformity is fully corrected and posture is normal. She showed dramatic psychological improvement.

FIG. 11

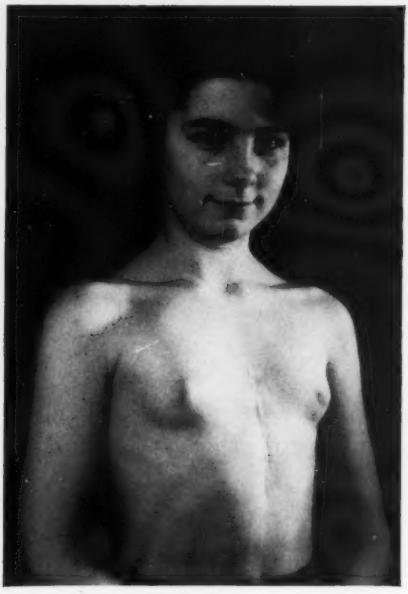

FIG. 12

Figure 11—Girl aged twelve years with progressive chest deformity and postural deterioration. Figure 12—Same girl six months after operation. Chest deformity is corrected and posture is normal.

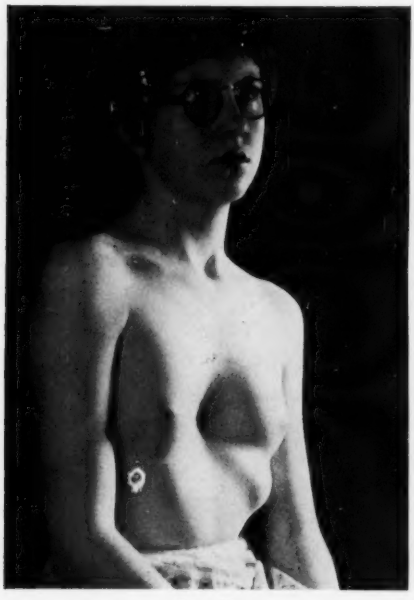

FIG. 13

FIG. 14

Figure 13—Girl aged twelve years with severe chest deformity and postural defects. A shy, retiring child who never played with others. Figure 14—Same girl six months after operation. Chest deformity is corrected and posture is normal. Marked psychological improvement.

two and a half years. In all cases the results have been excellent. In ten the chest deformity has been corrected. In one case, that of a boy of eleven at time of operation who had severe postural and chest deformities, there is still a mild depression of the sternum, but posture, physical activity and general health are so improved that he has become a promising young athlete (Figs. 5 and 6). The other ten children in the series not only show correction of the chest deformity, but their postural and physical abilities are now those of normal children (Figs. 7 to 14). The parents of all the children and the physiotherapists responsible for their post-operative treatment have confirmed the psychological change that followed operation, which in most cases has been more dramatic than the physical improvement.

SUMMARY

1. Funnel chest deformity is a common cause of progressive postural defects in children.
2. The underlying pathology of the funnel chest is a congenital deficiency of the muscle fibres of the anterior part of the diaphragm which allows the stronger posterior element to pull backwards the xiphoid and sternum. The postural changes are secondary to the chest deformity.
3. Operative correction of the chest deformity is described.
4. Post-operative physiotherapy is essential to correct the postural deformities. Patients must remain under orthopaedic supervision to maintain the correction obtained.
5. A series of twelve children treated by operation is reported, with excellent results in all.

I should like to acknowledge the help of my senior colleague, Mr I. S. Smillie, in the preparation of this paper; and the skill and enthusiasm of the physiotherapy staff of this hospital and of the Children's Orthopaedic Service, whose after-care has contributed largely to the satisfactory results of operative treatment.

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TIBIALIS ANTERIOR TRANSFER IN CONGENITAL CLUB FOOT

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In 1950 a clinic was started at the Royal National Orthopaedic Hospital for the treatment of incompletely corrected or relapsed club feet. With a few minor modifications the Kite method was followed closely until it was considered that satisfactory correction had been achieved. The details of our methods and early results have already been described (Fripp and Singer 1953).

There are two stages in the treatment: correcting the deformity and then maintaining the correction. We are not concerned in this paper with the first stage, but the second presents points of interest and difficulty. Kite (1930) keeps the corrected foot in a retentive plaster for six months in order to prevent relapse, but this has the disadvantage of prolonging the immobilisation in plaster, and it was hoped that transfer of the tibialis anterior tendon to the outer side of the foot would restore muscle balance and shorten treatment. No originality is claimed for this, and there have been other reports of the tibialis anterior transfer (Garceau 1940, Garceau and Manning 1947, Critchley and Taylor 1952, Carpenter and Huff 1953).

A recent follow-up of our cases has just been completed, and as our results differ in some respects from those formerly reported it was considered worth while to record them.

The patients in this series were, with a few exceptions, between the age of one and eight years when treatment started. They all had some residual deformity, due either to relapse of a well corrected foot or to incomplete initial correction. Previous treatment had consisted in the accepted methods and included Denis Browne splints, forcible manipulations under an anaesthetic and, in a few cases, open operation such as elongation of the calcaneal tendon.

Our patients initially had deformities that were resistant to treatment and the club foot was of the most severe type. Furthermore, the difficulty was increased in many by the stiffness caused by forcible manipulations. Therefore the feet that came under our care constituted a "difficult" group.

CLINICAL MATERIAL

Sixty-one patients were reviewed, of whom thirty-three had both feet deformed and twenty-eight one foot, making a total of ninety-four feet. Seventy-six tendon transfers were performed, the average age at operation being four years nine months.

TECHNIQUE OF OPERATION

In seventy feet the tibialis anterior tendon was detached from its insertion into the medial cuneiform bone and the base of the first metatarsal bone, and transferred to the peroneus brevis tendon near its insertion. The tibialis anterior was buttonholed through the peroneus brevis tendon and then sutured to itself and to the peroneus brevis. In the remaining six feet the tibialis anterior tendon was inserted into one of the cuneiforms or the cuboid, just lateral to the midline. The leg was immobilised in a below-knee plaster in the "over-corrected" position for six weeks, after which the patient received a course of re-educative exercises.

RESULTS

For this review a *relapse* was defined as the return of a foot to a state in which it was not plantigrade and either the adduction, inversion or equinus components of the deformity were not corrected to the neutral position.

There were fifty-two relapses, and in every one the principal component, and usually the only one, was equinus. The pitch varied from a third of an inch to one and three-quarters inch (pitch is the expression of the extent of equinus in terms of the distance between the under-surface of the heel and the floor). In most patients when the knee was flexed to 30 degrees the pitch increased by as much as half an inch to an inch. This is contrary to what we expected, because with the gastrocnemei relaxed the pitch should have decreased. The explanation of this paradox is that some of the equinus is compensated for by the

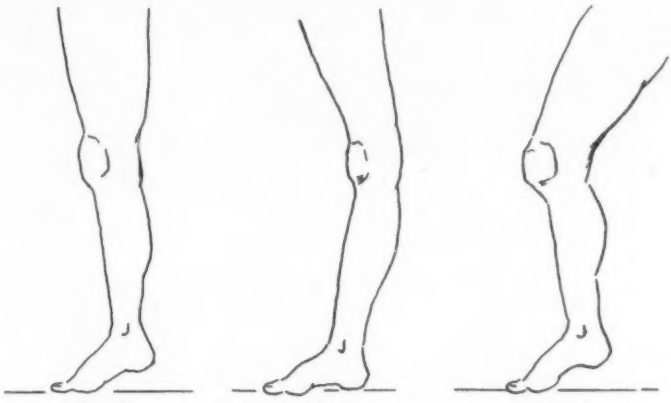

FIG. 1 FIG. 2 FIG. 3

Figure 1—Club foot with equinus deformity. Figure 2—Equinus masked by hyperextension of the knee. Figure 3—Unmasking of equinus by knee flexion.

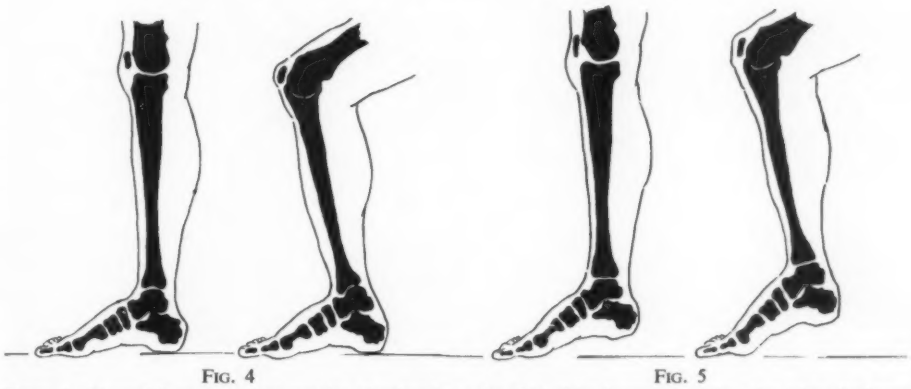

FIG. 4 FIG. 5

Figure 4—Normal foot. The foot remains plantigrade as the tibia glides forwards on the talus when the knee is flexed 30 degrees. Figure 5—Club foot with flat-topped talus. The pitch is increased with knee flexion because the tibia is unable to glide forwards on the deformed talus.

development of hyperextension of the knee, flexion at the hip and lumbar lordosis. The foot thus appears plantigrade, but there is complete lack of springiness in the gait, and the attitude of the patient is distinctive if the deformity is well marked. The true extent of the equinus becomes manifest when the knee is flexed and the lumbar spine flattened. This test for occult equinus resembles Thomas's test for fixed flexion deformity of the hip. Furthermore, in some cases of prolonged deformity there is incongruity in the ankle mortise from a flat-topped talus. When the knee is flexed the tibia cannot glide forwards on the talus; so the heel comes up off the floor (Figs. 1 to 5).

The relapse rate of fifty-two out of seventy-six transfers is considerable, even allowing that these feet were all " difficult " and that some of the relapses would be considered mild (Table I).

TABLE I

ANALYSIS OF RELAPSES AFTER TRANSFER OF TIBIALIS ANTERIOR FOR CLUB FOOT

Transfer	Number	Relapses	Component	Time after the operation
Tibialis anterior to peroneus brevis	70	50	Equinus	1 year 4 months (average)
Tibialis anterior to just beyond the midline	6	2	Equinus	Shortest—4 months Longest—7 years 2 months

Sequelae of the operation—It was thought that transfer of tibialis anterior might be followed by a dorsiflexed (cocked-up) big toe and dropped first metatarsal head, as is seen in feet in which the muscle actions of extensor hallucis longus and peroneus longus are unopposed. The cocked-up big toe occurs particularly in those club feet in which the plantaris or forefoot equinus element is marked and is comparable to that seen in the pes cavus. It may possibly be associated with the original deformity rather than with the transfer. Although there was evidence of a cocked-up big toe in fifty-seven feet in this series, the deformity was never severe and it did not give rise to symptoms.

TABLE II

SEQUELAE OF TIBIALIS ANTERIOR TRANSFER FOR CLUB FOOT

	Mild to moderate	Severe	Pain	Length of time after operation
Dorsiflexed big toe . . .	57	0	0	3½ years (average) Shortest—6 months Longest—7 years
Forefoot pronation over 10 degrees	11	—	—	
Depression in shoe under first metatarsal head . . .	21	—	—	

In only eleven feet was there evidence of over-action of the transfer with more than 10 degrees of pronation of the forefoot when the foot was actively dorsiflexed. All the shoes were examined; twenty-one had a depression under the first metatarsal head (Table II).

DISCUSSION

Serial wedged plasters, sometimes supplemented by a soft-tissue operation (Brockman 1930), do correct the vast majority of difficult and relapsed congenital club feet. Like Garceau (1940) and others, we attributed recurrence after correction to a relative peroneal insufficiency, and the operation of transfer of the tibialis anterior tendon was based on the premise that this muscle is the most powerful deforming factor. In this review the criteria of relapse were strictly adhered to, so that some of the cases included were mild. But the relapse after tibialis anterior transfer was frequent and always in the direction of equinus.

It might be supposed that the operation would be more successful if transfer were to the midline or just beyond it. Evidence against this hypothesis is obtained from Carr (1956),

who transferred the tibialis anterior just lateral to the midline in fifteen comparable feet which had been corrected by serial wedged plasters; twelve of these subsequently relapsed into equinus.

If transfer of tibialis anterior encourages recurrence of equinus—and we do not know that it does—it probably does so because its new insertion makes it a mechanically less efficient dorsiflexor and because transfer always weakens a muscle.

It is interesting that in 53 per cent of feet in the series equinus and plantaris (forefoot equinus) was the predominant component of the deformity before the serial wedging was started. This is in accord with the experience of Kite (1953) who stated that it is the equinus that recurs first without tibialis transfer.

All the patients were kept under careful review and in many cases the relapse into equinus occurred several months, and in a few cases years, after treatment had been completed. Occasionally the parents noticed quite a rapid onset of the recurrence, not associated with intercurrent illness or other obvious factors. The reason for this late recurrence was not apparent.

In some cases the balance of the foot had been further disturbed because the transposed muscle had caused excessive pronation of the forefoot, and in three patients there was excessive valgus of the hindfoot so that the tendon had to be retransferred to the midline. Thus, this operation may replace one deformity by another. This feature has troubled other surgeons: Moore (quoted by Kite 1947) abandoned the operation twenty-four years ago because "the foot was thrown out of balance as time went on," and Camera (1950) devised the procedure of transferring the lateral two tendons of extensor digitorum longus to the distal third of the fifth metatarsal because he believed that the tibialis anterior transfer would lead to over-correction.

SUMMARY

1. The results of seventy-six transfers of the tibialis anterior tendon to the outer side of the foot to prevent relapse of congenital club foot are reviewed.
2. There were relapses in fifty-two of the seventy-six feet on which the operation had been performed.
3. The equinus component of the deformity is the dominant feature in all the relapses.
4. A test for occult equinus is described.
5. The factors contributing to the high relapse rate are discussed.

We are grateful to Miss S. Girardin for the diagrams.

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SARCOIDOSIS OF HANDS

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The various manifestations of the complex disease known as sarcoidosis have only been recognised in recent years. The stages in its recognition have been well summarised by Gray (1941). In 1889 Besnier described a symmetrical granulomatous condition of the nose, ears and fingers which he called "lupus pernio." In 1899 Boeck reported a skin disorder characterised by the appearance on the face of granulomatous swellings resembling lupus vulgaris, and coined the name "cutaneous sarcoid." It was recognised in 1898 by Hutchinson, who called it "Mortimer's malady" after the patient concerned. In 1917 Schaumann showed that these conditions were variants of the same disease and merely cutaneous manifestations of a disorder affecting many organs such as the lymphatic system, the bone marrow, the lungs and other viscera.

According to Ellis (1940), Jüngling in 1920 reported sarcoid lesions of the bones of the extremities under the title "osteitis tuberculosa multiplex cystica." Later he substituted the word "cystoides" for "cystica," because the lesions are in fact solid and only appear cystic in the radiographs. Ellis emphasised that Jüngling's disease is not cystic tuberculosis of bone, and that the radiographic appearance is due to replacement of bone and marrow by sarcoid material.

McCort, Wood, Hamilton and Ehrlich (1947), in a series of twenty-seven cases of sarcoid, found six with lesions in the hands, though none of these patients had any symptom referable to the bony changes. The osseous involvement was of two types: one the condition described by Jüngling, and the other a diffuse rarefaction with reduction in the number of bony trabeculae in the medulla and slight thinning of the cortex. Riley (1950), in a series of fifty-two cases, reported osseous lesions in the extremities in 13 per cent, mainly in the phalanges. The lesions were either localised punched-out "cystic" areas without evidence of surrounding inflammatory reaction, or a striking alteration of the trabecular structure of the bone with extensive cortical atrophy and resorption, as in the present case. A coarsely reticulated appearance of the medulla was characteristic. Holt and Owens (1949) found nine cases of bone involvement in fifty-five cases. They regarded the middle and distal phalanges of the hands and feet as the commonest sites of bone lesions. Longcope and Freiman (1952) found nineteen bone lesions in 100 cases. Mather (1957) reported that in a recent survey, with control radiographs, bone changes were found in only nine out of the 120 patients. He suggested that the lower frequency in this series may be because most of the patients had predominantly intrathoracic sarcoidosis; there were only thirteen cases of skin sarcoid, of which five showed digital bone disease. Sarcoid foci had in fact been reported in almost every bone, but they are of diagnostic value only in the hands and feet.

When sarcoid is present in the marrow, secondary changes appear in the adjacent bone in one of several patterns. If the disease progresses slowly, lacunar resorption occurs over a relatively large area, but most intensely at the distal ends of the proximal and middle phalanges, where localised cavities form. In addition, perivascular infiltration of Haversian canals may occur, with consequent thinning of the cortex and destruction of the finer trabeculae. In the very early stages of the disease there is non-specific osteoporosis which is later supplanted by a lace-work pattern of bone destruction—the commonest and most specific radiological manifestation of osseous sarcoid.

Calcium metabolism—Mather (1957) stated that hypercalcaemia occurs so infrequently in patients with sarcoidosis not receiving vitamin D that routine estimation of the serum calcium

is unnecessary. He reported nine cases with bone lesions and no upset of calcium metabolism. In the case of bone sarcoidosis reported here the first serum calcium estimation by the Kramer and Tisdall method, 13·5 milligrams per cent, was well above normal, though it became a low normal figure, 9·3 milligrams per cent, before calciferol therapy was started.

CASE REPORT

A typist then aged twenty-two years was first seen by us in February 1951. In 1943, when she was fourteen years old and otherwise healthy she began to notice burning pain and swelling in the middle finger of the left hand. In 1944 the finger was amputated through the middle phalanx. In 1945 the same condition began in the corresponding finger of the right hand, and it too was partially amputated in 1946. Other regions of both hands became involved to a somewhat lesser extent, as shown in Figure 1.

The patient said that the condition began in each finger with a burning pain which lasted four or five days. Then the pain would subside and the swelling remain. If the tip of a finger

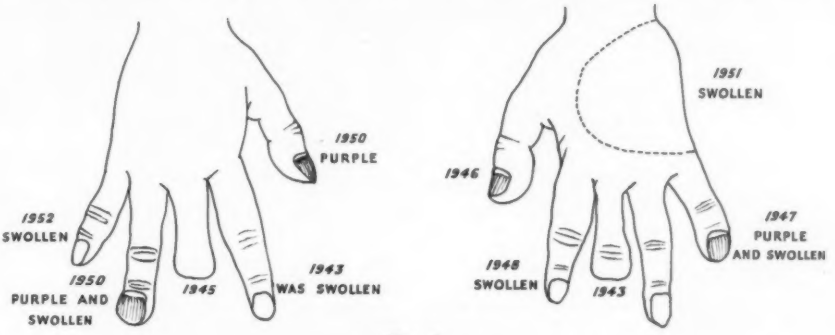

FIG. 1
Diagram showing progression of the disease. All dates refer to onset.

were involved the nail became wider than normal and sometimes became brittle and striated longitudinally; if the base of a finger were involved the nail was not affected. Her hands became tired if she worked much, and because of the amputations she was no longer able to use a typewriter. The feet were not affected. She had no chest trouble and there was no family history of tuberculosis.

At the time of examination she complained of burning pain and swelling in the thumb, index finger, little finger and ulnar area of the back of the left hand, and in the thumb, ring and little fingers of the right hand. The affected skin was reddish-blue and in the swollen regions the skin was shiny and smooth (Fig. 2). The tips of the remaining affected fingers were bulbous. The amputated fingers were also bulbous and the tips of the stumps were a little blue. The ulnar part of the back of the left hand was oedematous. Movement of the fingers was free. There was no sign of peripheral nerve involvement and the circulation in both hands appeared normal. There were no other clinical signs of sarcoid elsewhere in the body.

From inquiries it was clear that the condition had originally been treated as a fungus infection, though there had been no purulent discharge except for a short time from the right ring finger. The opportunity for biopsy afforded by the amputations had been missed.

It was felt that the condition was most likely to be Boeck's sarcoid affecting the fingers. Because the patient lived in the country it was only possible to see her at infrequent intervals. The investigations were not complete until June 1951, when the diagnosis was established mainly from biopsy of the skin and from the radiographic appearance of the fingers.

Investigations—The Mantoux test, the Wassermann reaction, the sedimentation rate, the blood count and a search for fungus infection gave no positive information. A number of tests more specifically related to sarcoidosis gave the following results:

Serum protein—Total protein was 7·5 grammes per cent (globulin 3·9 grammes per cent; albumen 3·6 grammes per cent). *Blood calcium*—(February 1951) 13·5 milligrams per 100 millilitres; (June 1951) 11·2 milligrams per 100 millilitres; (March 1952) 9·3 milligrams per 100 millilitres. *Alkaline phosphatase*—4·3 King-Armstrong units. *Uveal tract*—No sarcoid deposits seen on examination with slit lamp.

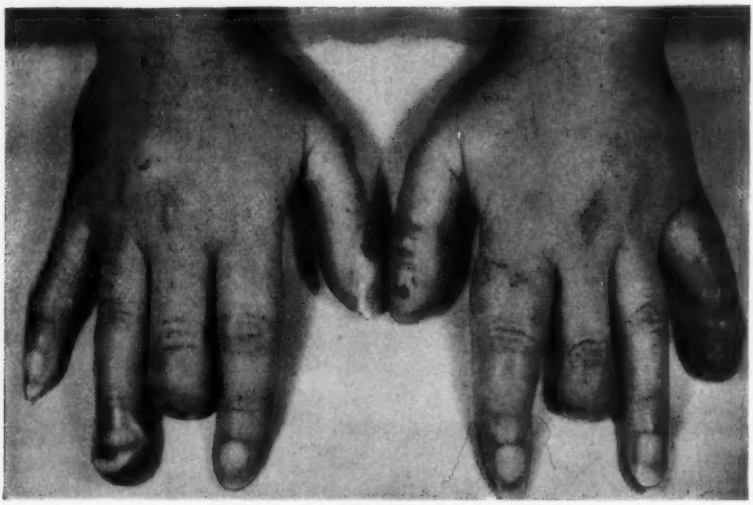

FIG. 2
Photograph of the hands in 1951, before treatment was begun.

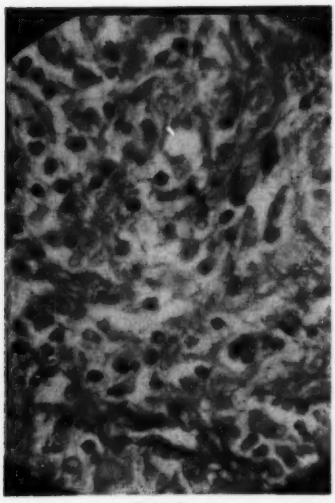

FIG. 3

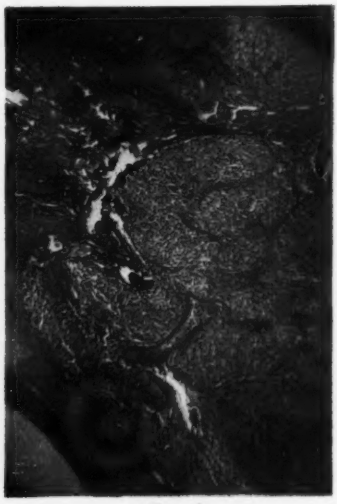

FIG. 4
Low-power and high-power photomicrographs of sections from the skin of the ulnar side of the left hand, obtained at biopsy.

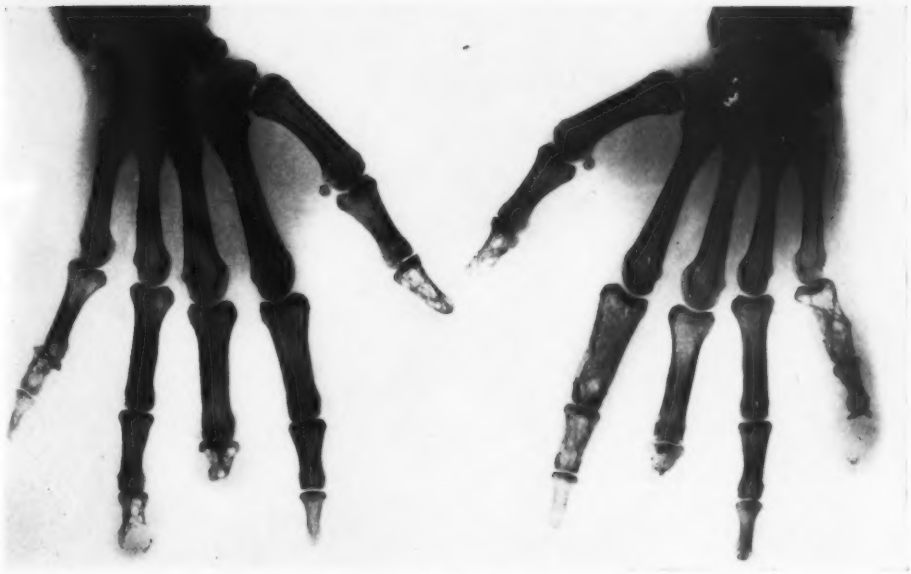

FIG. 5
Radiographs of the hands in 1951, before treatment was begun.

Biopsy—Needle biopsy of an affected phalanx showed no sign of sarcoid. Skin biopsy from the ulnar side of the left hand (Dr R. P. Towers) showed, in the dermis, several follicles of epitheloid cells, well demarcated, with only very few surrounding lymphocytes. There was no trace of caseation. The appearances were those of sarcoidosis (Figs. 3 and 4).

Radiographic examination—There was coarse expansion of the trabecular structure characteristic of Boeck's disease (Figs. 5 and 6). The pattern of bone damage closely followed the superficial changes except for the absence of bone change in relation to the swollen ulnar side of the left hand. There was almost complete disappearance of the phalanges in the tips of the severely involved right ring and left little fingers. Radiographs of the feet showed no bony changes. The radiograph of the chest showed a slight increase in striation, not typical of sarcoid.

Sarcoid material was not readily available at that time, so the Kveim test was not carried out.

Treatment—In June 1951 the patient was admitted to hospital and given 600 milligrams hydroxy-phenyl-cinchoninic acid a day for ten days. Three months later she reported that the hands felt better and were not so red. In March 1952 the renal function tests being satisfactory, 100,000 units of vitamin D_2 (calciferol) daily were prescribed. Because of nausea and vomiting, the dose was reduced to 50,000 units daily in the following month, and this dosage was continued for six months. Owing to the striking improvement (Fig. 7) treatment was then stopped.

When last seen by us in May 1955 the patient had no complaints and the hands looked quite healthy. The colour was

FIG. 6
Contact print from radiograph of left index finger showing the trabecular structure seen typically in Boeck's sarcoidosis.

FIG. 7
Photograph of the hands at the completion of treatment.

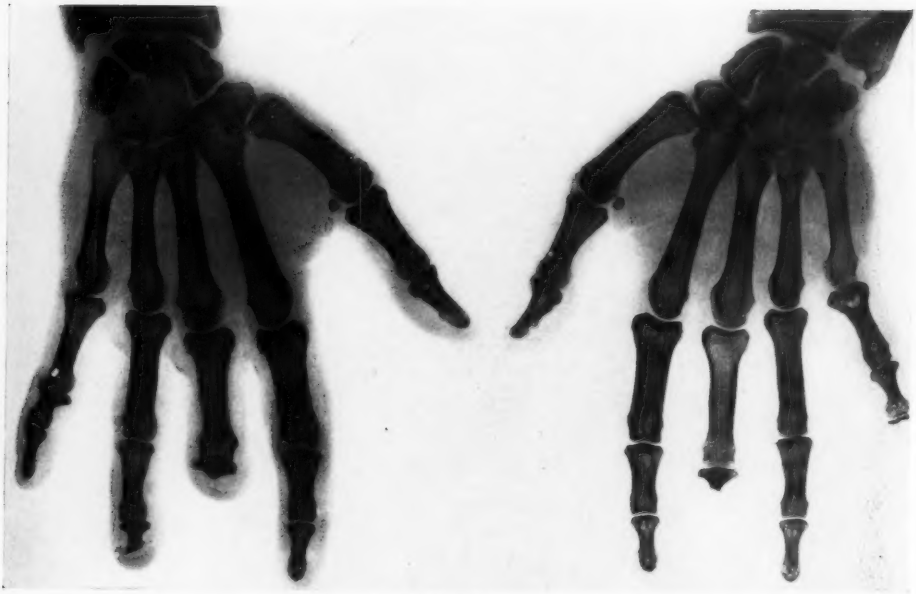

FIG. 8
Radiograph of the hands in 1957, five years after the completion of treatment.

good, there was no swelling, and the nails had largely recovered. An exception was the left little finger, the tip of which had atrophied.

A radiograph taken in February 1957 (Fig. 8) showed the improvement in the bony structure. At the same time the patient wrote to say that her hands remained healthy and that she had resumed work as a typist.

COMMENT

Failure to suspect this unusual but typical condition led to the unnecessary partial amputation of two fingers in a typist. The indolent history, the pain, the spread up the digits, the asymmetry of the involvement and the absence of pus should have brought sarcoidosis into consideration. Biopsy and radiography should have established the diagnosis.

The treatment of this patient raised some problems. Because she lived in the country it was not possible to keep her under constant supervision. The short course of hydroxyphenyl-cinchoninic acid appeared to improve the condition slightly, but it was not a drug that could be given safely for long. By March 1952 calciferol appeared to be the drug of choice and there seems to be little doubt that it was effective.

Goldsmith and Hellier (1954), summarising the results of other workers who have treated sarcoidosis with calciferol, state that opinions differ about its effect. On the one hand Dowling *et al.* (1948) saw improvement in six cases out of seven. On the other hand, Nelson (1949) saw no difference between eight patients treated with calciferol and eight controls, and Mather went so far as to state that complications are so frequent that its use should be discontinued.

When this case was under consideration, the place of cortisone and A.C.T.H. in the treatment of sarcoidosis had not been clearly defined, but it has now become clear that these drugs have a valuable suppressive action in sarcoidosis. Since the patient appeared to be responding well to calciferol, it was decided that there was no need to change her treatment. The improvement with calciferol appears to have been more than coincidence. It occurred promptly and has persisted for almost three years in a case in which symptoms had been troublesome for nearly ten years. This case, however, has been presented more particularly to illustrate the diagnostic features of sarcoidosis of the hands.

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CONGENITAL DISCOID CARTILAGE

Report of a Case of Discoid Medial Cartilage, with an Embryological Note

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and
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Discoid cartilage was first described in 1889 by Young, and for long was found affecting only the lateral cartilage. The " snapping knee " was described as a clinical sign of this condition by Kroiss in 1910. In 1930 Watson Jones described a ring-shaped medial cartilage in a thirty-four-year-old man with clicking at the inner side of his knee; there had been no history of injury. The cartilage was circular, with a thick margin all round its circumference and a central perforation with thin margins. Watson Jones suggested that there had been an old " bucket-handle " tear, the inner segment of which had been carried in towards the centre of the joint. A similar specimen was found in class-room dissecting and was described by Basmajian (1952). In this case the other knee was found to have normal cartilages.

Apart from these two cases we have found four cases of true discoid medial cartilage in the literature. Cave and Staples described two cases in 1941, Dwyer and Taylor one in 1945, and Smillie one in 1948. From the descriptions it seems likely that three of these belong to the category which Smillie has termed " primitive." Such a cartilage is a complete plate with a thick free margin which may be convex.

Three of the discoid medial cartilages referred to had longitudinal tears and the fourth showed cystic degeneration and horizontal cleavage. Horizontal cleavage, which according to Smillie occurs characteristically in the primitive type, was also present in one of the three with longitudinal tears.

CASE REPORT

A woman aged twenty-seven came to hospital with a three years' history of pain at the medial side of her left knee. The pain was felt on rotational strains, and was of insidious onset. Eleven months before her admission she had twisted the knee, and thereafter the symptoms had become worse. Eight months later she had experienced a loud and painful " click " at the medial side of the left knee on straightening it. This was followed by swelling of the knee, inability to straighten it fully, and a slight limp. These symptoms persisted in mild degree until she was referred to hospital.

On examination there was tenderness over the joint line in front of the medial ligament. On flexion and rotation medially and laterally a click was felt inside the joint, but it was difficult to localise it precisely. There was slight elastic limitation of full extension. There was no effusion. The radiological appearances were normal.

A diagnosis of a tear of the anterior part of the left medial cartilage was made. At operation (March 1957) a longitudinal tear about half an inch (1·25 centimetres) long was found extending backwards from the anterior horn. When the anterior attachment had been freed it was seen that the cartilage was of unusual shape, extending laterally as a solid disc over the upper surface of the tibia. The cartilage was excised entire.

On examination after fixation the cartilage was seen to be an oval disc 4·5 centimetres long by 2·5 centimetres wide (Fig. 1). It was a solid plaque, 2·5 millimetres thick at the centre. The lateral border was free, convex, and 1·5 millimetres thick. The medial border was the

normal fibrous periphery of a medial cartilage. Anteriorly the longitudinal tear was seen extending backwards from the anterior horn into the cartilage as noted at the operation. No horizontal cleavage or cystic changes were seen, and no ridges on its superior surface.

The patient's daughter was also found to have symptoms referable to one of her knees. At the age of six weeks this child was noticed by Mr I. S. Kirkland to have a clicking left knee and the ligaments were so lax that the knee could easily be subluxated. This abnormality has gradually become less obvious, the child now being twenty months old.

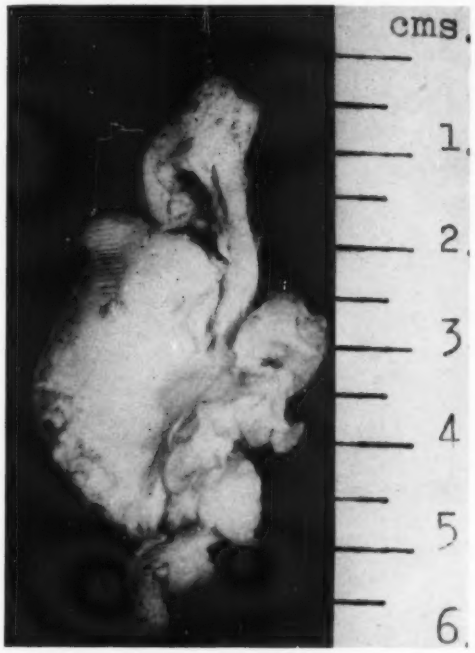

FIG. 1

Photograph of discoid medial cartilage removed at operation, with centimetre scale alongside the medial border. Note the anterior split (between 1 and 2 centimetre mark) and the convex free (lateral) border. The faint horizontal grooves anteriorly are where the cartilage was gripped by forceps.

DISCUSSION

It has been postulated that the occurrence of discoid cartilage is due to the persistence of the foetal state, and Smillie (1948) stated that the shape of a normal cartilage is the result of gradual absorption during the latter half of foetal life of the central part of an originally complete plate. Such a view on the development of the cartilages is often taught, but it does not seem to be substantiated by a critical analysis of the development of the knee joint. Jaroschy (1935) wrote " We are not entitled to relate the disc-shaped fibrocartilage to a standstill in development, or the persistence of an earlier state. Study of the development of the knee joint is against such a theory. The lateral cartilages of new-born babies and premature babies often cover a larger area of the tibia than in adults, but do not differ greatly in shape from the adult cartilage except in rare examples which may be regarded as pathological. The theory that the fibrocartilages are to be considered as remains of complete intra-articular

discs is lacking in proof. In the animal kingdom disc-shaped lateral cartilages are not found in mammals, but they are constantly found in birds and many reptiles. The theory that the disc-shaped lateral cartilages in man represent a reversion to the condition in reptiles is not proved."

Kaplan also found (1955) that the fibrocartilages of the knee do not present at any phase of foetal development a disc-like appearance, either on the lateral or medial side, and he was unable to accept the thesis that the discoid cartilage is the result of arrest of development. Kaplan's study covered embryos from forty days (14 millimetres) to birth and showed that the earliest development that could be considered the precursor of the semilunar cartilage took place at the periphery of the joint.

In view of the conflicting views about the origin of discoid fibrocartilages one of us (T. A. E.) carried out some dissections of foetal limbs to throw some light on the problem.

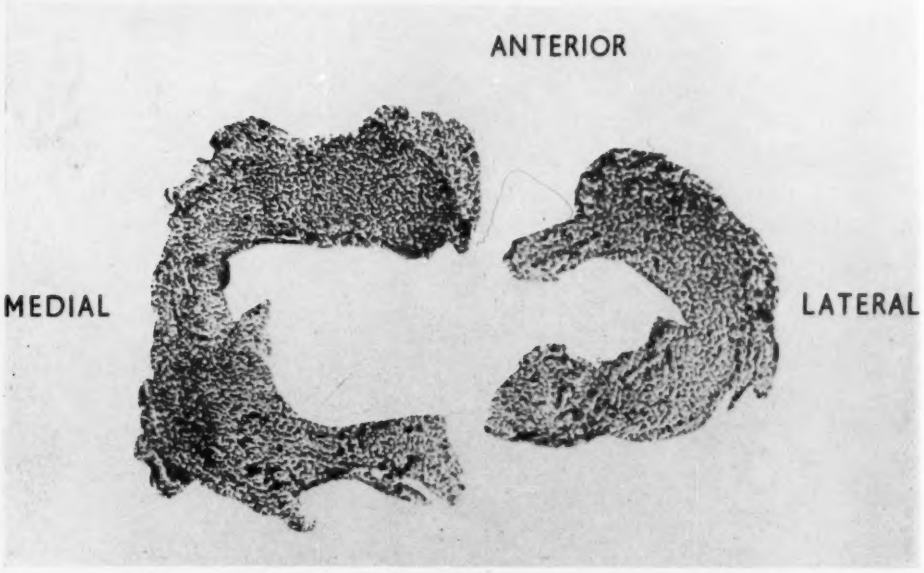

FIG. 2
Cartilages from right knee joint of 37 millimetres (ten weeks) embryo. (×60.) The cartilages have almost the adult form.

It was found that as early as the tenth week the cartilages have a form which closely resembles that in the adult (Fig. 2), and nothing could be more distinct than the difference between the medial cartilage in the ten-weeks'-old foetus and the discoid cartilage from our patient. Further dissections confirmed that the cartilages retain this form throughout intra-uterine life. An example from a 145 millimetre foetus (eighteen weeks) is shown in Figures 3 and 4.

It is perhaps inaccurate to say that the disc shape is never present in the normal development of a fibrocartilage. In an early phase of development there is an undifferentiated mass of mesenchyme between the cartilaginous precursors of the bones. In most synovial joints this intermediate mesenchymal plate or blastemal matrix breaks down to form a space between the two bones by the end of the second month (Quain 1908). In some synovial joints parts of the mesenchyme persist to form intra-articular structures such as the fibrocartilages in the knee (Gray's Anatomy 1949). There is no embryological evidence to suggest that this undifferentiated mesenchyme normally goes on to form a complete disc of fibrocartilage whose

central portion is later absorbed to produce the adult semilunar form. All embryological evidence indicates that the central part of the plate of mesenchyme is absorbed when the joint space is developing, and from the commencement of differentiation the cartilages have

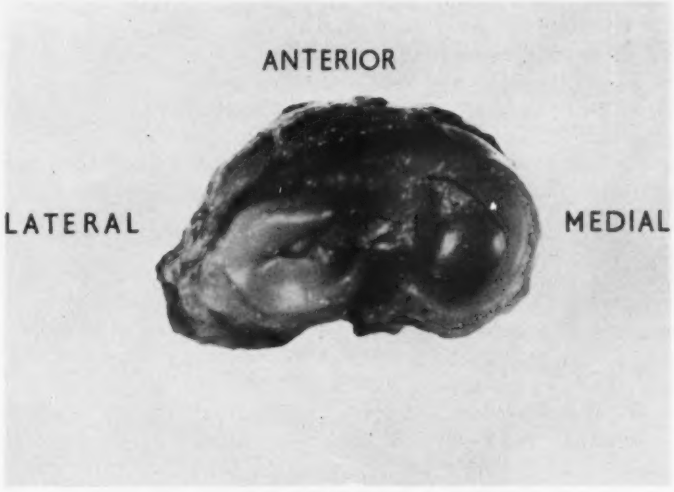

FIG. 3
Dissection from 145 millimetres (eighteen weeks) embryo showing the upper surface of the left tibia with the cartilages *in situ*. (×6.)

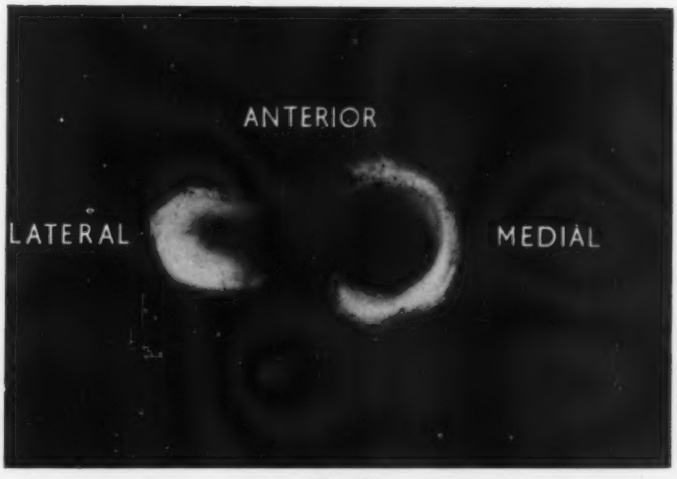

FIG. 4
Cartilages from the left knee joint of a 145 millimetres (eighteen weeks) embryo. The semilunar shape of the cartilages is well seen. (×6.)

a basic form like that of the adult. This view was also expressed by Hertwig (1892) who wrote: " Into the articular cavity are thrust from the articular capsule the metamorphosed products of the intermediate tissue which constitute the so-called semilunar fibrocartilages or the menisci." It is therefore only at the very earliest phase of development that the "plate"

of undifferentiated mesenchyme from which the cartilages develop can be said to be disc-shaped. The discoid cartilage cannot truly be said to be a persistence of a normal phase in development, because, from the time of differentiated mesenchyme, the cartilages have a semilunar form.

As to the etiology of the discoid form occurring in the lateral cartilage, Professor Walmsley (1957) expressed the following view: " I think we must always keep in mind the fact that the form of the lateral cartilage with its two horns so closely approximated does tend to have rather a discoid appearance. The semilunar form of the lateral cartilage is indeed dependent on a very minute central breakdown of the blastemal matrix between the precursors of the bone, and if this fails to occur, then I can well understand how a discoid-like cartilage might result. The fact that a disc-like cartilage is more common on the lateral side than on the medial is in keeping with the greater absorption of the blastema that occurs normally during the development of the medial cartilage, and it is this greater absorption that results in the more ' open ' form of this cartilage."

Discoid cartilage is found comparatively rarely, but it is possible that it often goes unrecognised (Fisher 1936). Middleton (1936) gave a chronological list of references to the previously recorded cases of discoid lateral cartilage, but made no mention of discoid medial cartilage. Smillie (1948) found twenty-nine examples of discoid cartilage in 1,300 knees subjected to operation, only one of which was on the medial side. This figure, however, represents only the incidence of discoid cartilage in patients operated upon for suspected cartilage tears. Whether discoid cartilages are more liable to suffer tears than normal cartilages is not known, for we have no knowledge of the true incidence of this anomaly; but Middleton considered that on the lateral side the disc-shaped cartilage is abnormally prone to injury. Likewise, in the absence of a knowledge of the incidence of discoid cartilage, it is useless to speculate on whether the greater rarity of the anomaly on the medial side is true or only apparent. It is of interest that other congenital anomalies are commoner on the fibular side than on the tibial side (Steindler 1950), and that, as Walmsley points out, the shape of the lateral cartilage is such that the discoid form would be much more likely to occur than on the medial side.

Middleton considered that in such a developmental abnormality as discoid cartilage, inheritance almost certainly plays a part in its transmission. He referred to a case recorded by Jones (1935) in which the mother of the affected child showed similar symptoms, and a discoid cartilage was believed to be responsible, though it was not proved by operation. This was the only case with a history of familial transmission in Middleton's series. In our case the patient's daughter had an abnormality of the knee, but so far its nature has not been proved by operation.

In some cases of lateral discoid cartilage associated defects have been noted of the fibular side of the leg. These include high fibular head, defects in the fibular musculature, peroneal luxation and changes in the shape of the lateral malleolus (Lewin 1952).

Apart from slight flattening of the medial femoral condyle which appears to be within the normal range, no such defects were found on the corresponding side of the leg in our case. No comment was made on this particular feature in the other cases of discoid medial cartilage previously described.

The cases of discoid medial cartilage have all been diagnosed clinically as torn medial cartilages, and the discoid nature of the cartilage has been found incidentally at operation. Dwyer and Taylor's (1945) patient and our patient both experienced loud and painful clicks in the knee, which, if occurring on the outer side of the knee, would have suggested a discoid lateral cartilage. Middleton (1936), discussing the cause of the snapping noise in such cases, considered that the mere presence of a disc-shaped cartilage did not cause symptoms, but symptoms necessitating removal of the structure may be brought about by injury, and by a ridge developed on the upper surface of the cartilage. When the knee is extended the femoral condyle rides over this ridge, producing the characteristic snapping noise. In our case of

discoid medial cartilage there was no ridge on the surface, and the snapping must be ascribed to the associated tear of the anterior horn. Thus no specific diagnostic features can be said to have been found so far in discoid medial cartilage.

SUMMARY

1. A case of discoid medial cartilage is described—the fifth so far recorded—and comparison is made with the previous cases in the literature.
2. The origin of the anomaly, its incidence and clinical features are discussed.
3. The view is expressed that discoid cartilage is a congenital lesion due to abnormal development, fibrocartilage being laid down in mesenchyme which normally disappears in the formation of the joint. It is not the effect of arrest of a normal process or persistence of a normal foetal state. The only time at which a cartilage may be said to be disc-shaped is in the earliest weeks of embryonic life, when the disc or plaque of undifferentiated mesenchyme is present between the developing bones. The central part of this mass disappears early, and the fibrocartilage develops in its peripheral portion. In a ten-weeks'-old embryo (37 millimetres) the cartilages were shown to have a crescentic shape like that of the adult cartilage.

We are very grateful to Professor Robert Walmsley for his stimulating interest in this study and for his most helpful constructive criticism in the preparation of this paper.

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TWO CASES OF DISCOID MEDIAL CARTILAGE

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A discoid medial cartilage must be uncommon; I have found reports of only two cases in the literature. Dwyer and Taylor described a torn discoid medial cartilage in 1945. This cartilage had a longitudinal split extending from front to back and another tear similar to the horizontal cleavage described in discoid lateral cartilages by Smillie (1946). In Smillie's (*loc. cit.*) own case of a discoid medial cartilage there had also been a horizontal cleavage, and the cartilage showed cystic degeneration peripherally. Both these were of the " primitive " type in Smillie's classification of discoid cartilages.

CASE REPORTS

Case 1—A man aged twenty-four years complained of locking incidents in his right knee when getting up from a chair or from a squatting position. He recalled a fall a year before when he twisted the knee. He was not aware of locking until the next day. Clinically, there was a moderate effusion; there was no block to extension. The medial joint line was tender

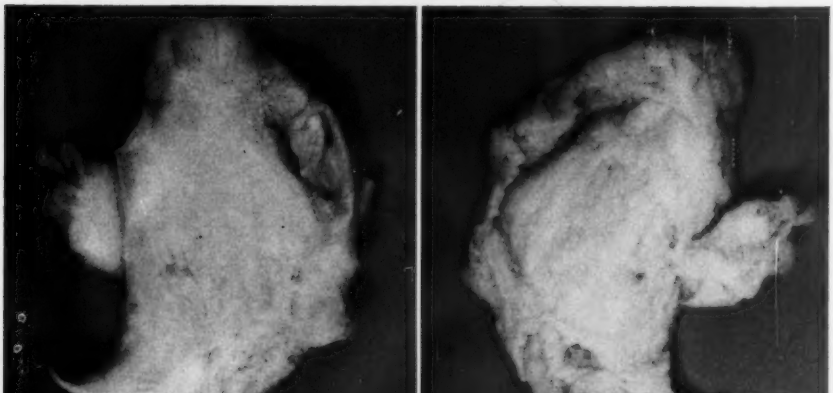

FIG. 1

Case 1—Upper and lower surfaces of the excised cartilage.

and pain was elicited medially by rotation of the tibia on the femur in both directions. A faint click was elicited only once. Radiographs of the knee were normal. At operation (Dr H. C. Palin) a discoid semilunar cartilage was removed from the inner side of the joint (Fig. 1). It was like the " intermediate " type of discoid lateral cartilage described by Smillie. A tag projected from the inferior surface at the free edge of the cartilage, and there was a small longitudinal peripheral tear. The tag was part of a horizontal cleavage on the under-surface.

Case 2—A youth aged eighteen years stated, during his treatment for a fractured tibia, that since the age of twelve he had suffered repeated locking incidents associated with a " slipping " sensation on the inner side of his left knee. He had always been able to unlock it himself. He declared that his knee was locked in the long-leg plaster in which his fracture was being treated. When the fracture was united he was admitted to hospital where the joint was explored. A discoid medial semilunar cartilage was found. The central free margin was

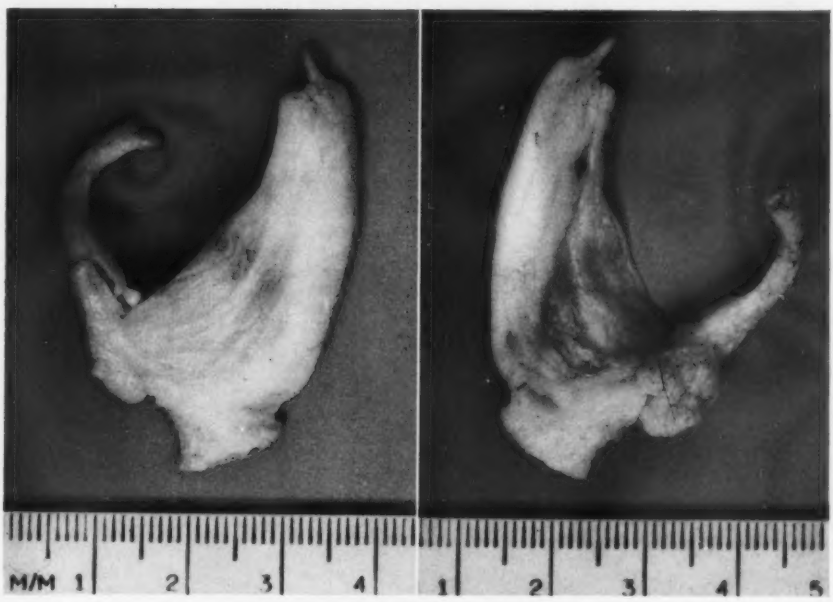

FIG. 2
Case 2—Upper and lower surfaces of the excised cartilage.

hypertrophied and rounded, and between this and a thin cord-like peripheral rim was an intermediate thin, almost membranous part which was incomplete posteriorly (Fig. 2). Presumably a longitudinal tear had developed, but had not extended more than half-way round the periphery. Seemingly the central free margin had become hypertrophied where it had become displaced from under the femoral condyle, and the intermediate part had become thinned by the pressure of this condyle. This cartilage probably represents the " infantile " type of Smillie's classification, or perhaps an " intermediate " type, the thin central margin having hypertrophied.

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RECURRENT SPRAIN OF THE ANKLE JOINT WITH DIASTASIS

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We believe that diastasis of the ankle joint is a common cause of recurrent sprains. It is not well recognised, although it has been described by various authors, notably by Outland (1943). The true incidence of partial diastasis in recurrent sprains is not known, but we believe it to be 70 or 80 per cent.

In this paper we describe the treatment of recurrent sprains by stabilisation of the inferior tibio-fibular joint with a lag screw.

CLINICAL MATERIAL

Seventy-five patients were treated in this series. Their ages ranged from sixteen to sixty-five years with an approximately equal sex incidence. The condition has also been recognised in children from the age of eight years, but operaton has not been used. Gross diastasis which is quite obvious is excluded from this study.

CLINICAL FEATURES

History—There is a history of injury to the ankle—usually a sprain—and from then on the patient has a weak ankle, which is sprained repeatedly. A prominent feature is a sense of instability of the ankle. There is a chronic aching pain, with tiredness. Pain is often felt over the lateral ligament.

Examination—*In acute cases* there are pain, swelling and discoloration. Tenderness to palpation may be generalised over the usual ligamentous areas, but there is also specially marked tenderness over the anterior inferior tibio-fibular ligament, and possibly over the posterior inferior tibio-fibular ligaments. The patient is unable to bear weight. The talus can be rocked from side to side with a characteristic feeling of a click in the ankle mortise. This is elicited by holding the talus just below the malleoli with the foot at right angles and sliding it from side to side. The leg must be held well above the malleoli, so that there is no compression and narrowing of the ankle mortise. It is important to exclude inversion and eversion at the subtalar joint. This " rocking " causes pain, which in acute cases interferes with the examination, and an anaesthetic may be required. In some cases a slight rock is normal and this can be checked by testing the uninjured ankle. *In chronic cases* there may be no obvious swelling, but widening of the malleoli may be apparent. There is usually tenderness over the anterior inferior tibio-fibular ligament, and the typical side-to-side " rock " of the talus can sometimes be eliminated or markedly diminished by compression of the malleoli. This confirms the diagnosis. There is usually pain on " rocking," and in old cases there may be crepitus. Movements of the joint otherwise are full and pain-free.

Radiographic features—Radiographs of the ankle taken in full inversion and in full eversion show the following features. 1) Tilting of the talus in relation to the inferior articular surface of the tibia. Tilting is more usually shown on inversion, unless the inner part of the medial ligament is torn, in which case tilting can be shown also on eversion. 2) There is sometimes a perceptible widening of the syndesmosis between the tibia and the fibula just above its articular surface. 3) In chronic cases roughening of the tibia and fibula may be present where the ligaments have been avulsed.

TREATMENT

Costigan (1953) used a stainless steel screw across the tibio-fibular syndesmosis with apparently satisfactory results in twenty-five cases and did not find it necessary to remove the screw. Lee and Horan (1943) passed threaded Kirschner wires through the tibia and fibula and drew the bones together with thumb nuts. Leonard (1949) treated fifty-one patients by

FIG. 1
Case 1—Radiographs showing, on both sides, tilting of the talus on inversion.

FIG. 2
Case 1—After stabilisation of the inferior tibio-fibular joint with a lag screw.

immobilisation in a walking plaster for six weeks. Outland (1943) also used plaster, but he believed that tibio-fibular fusion might be necessary in chronic cases.

We have been disappointed with conservative methods in both acute and chronic cases, and for the last six years we have always advised operative stabilisation with a lag screw.

OPERATION

The lower end of the fibula is exposed, and a hole is drilled through the fibula into the tibia with a slight cranial and anterior inclination. The hole must be as low as possible so that the screw will exert pressure at the junction of the articular surfaces of the fibula and tibia. A Johannsen lag screw (usually $1\frac{3}{4}$ inches long) is inserted into the drill-hole and driven firmly home. After this the " rocking " test will show whether the reconstruction has been effective.

Post-operative care—Immobilisation in plaster is not required. After three or four days in bed with the foot elevated ankle movements are encouraged and the patient is allowed up. Swelling of the ankle sometimes persists for a few weeks, but this gradually disappears. Some patients may be comforted by a crepe bandage, but there is no clinical necessity for this.

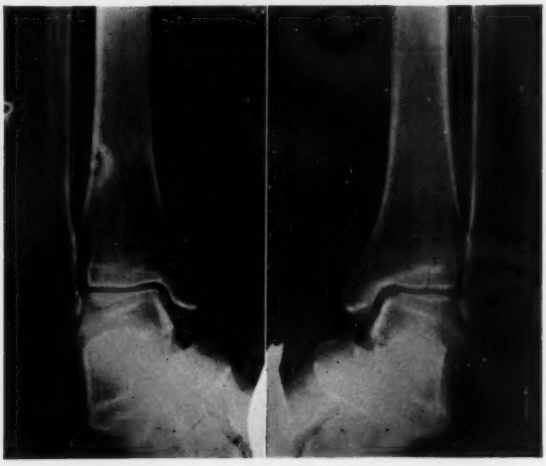

FIG. 3
Case 2—Tilting of left talus on inversion. The right ankle is shown for comparison.

COMMENTS

Only a lag screw gives the necessary compression at the tibio-fibular syndesmosis: it grips the cancellous bone well, counter pressure being exerted on the fibula by the washer which should always be used. A Sherman screw does not give a compression force because of its fine thread. There has been no need to remove the screw.

The results in our seventy-five cases have been uniformly successful. We have not done this operation in children, because of the danger of disturbing the epiphysis.

Since our experience with these sprains we have treated ankle fractures with extra care, and frequently use screw fixation at the time of injury to avoid partial diastasis with its instability, recurrent sprains and later osteoarthritis. If it is not possible to operate at the time of the fracture because the fracture line traverses the site where one inserts the screw, operation is performed when the fracture has united.

ILLUSTRATIVE CASES

Case 1—A man aged twenty-six years complained of instability of both ankles since spraining them about two years before. Examination showed that movements were full and pain-free. There was tenderness over both anterior inferior tibio-fibular ligaments. The talus could be " rocked " in both ankles—especially the left, in which crepitus was marked. Radiographs showed tilting of the talus, on inversion only, in both ankles (Fig. 1). There was widening of the tibio-fibular syndesmosis,

especially of the right. The right fibula showed a roughened area where the periosteum had been torn by the pull of the ligaments. The tibio-fibular joint was stabilised by a lag screw on both sides (Fig. 2). The patient has returned to competitive badminton and leads a normal life, with no symptoms from either ankle.

Case 2—A woman aged forty-seven years complained that her left ankle had been weak for many years. She gave a history of having sprained the ankle some years previously. On examination, movements of the ankle were full and pain-free, but there was tenderness over the anterior inferior tibio-fibular ligaments, and the talus could be rocked. Radiographs showed tilting of the talus on both inversion and eversion, and perceptible widening of the tibio-fibular syndesmosis (Fig. 3). The tibio-fibular joint was stabilised by a lag screw. Since then she has had a stable ankle, a full range of movements, and has been back to her normal active life without symptoms.

SUMMARY

1. Partial diastasis of the tibio-fibular syndesmosis is believed to be common, but it is often overlooked as a cause of recurrent sprains of the ankle.

2. The treatment of recurrent sprains of the ankle by stabilising the inferior tibio-fibular joint with a lag screw is described. The method has been used in seventy-five patients aged between sixteen and sixty-five years. The longest follow-up has been six years.

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EXPERIMENTAL PRODUCTION OF CARTILAGE DURING THE REPAIR OF FRACTURES OF THE SKULL VAULT IN RATS

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Ham (1930) noted that the cartilaginous areas of fracture callus were poorly supplied with blood vessels, in contrast with the richly vascular new bone. He also pointed out that both bone and cartilage apparently developed from similar periosteal cells, and that the two tissues graded into one another. He therefore suggested that the osteogenic cells of the periosteum, during fracture repair, have dual potentiality, forming bone in places where the blood supply is adequate and cartilage where it is not. Urist and Johnson (1943), on the other hand, stated that the avascularity of callus cartilage is secondary, and is caused by the blood vessels' being pushed aside as the cartilage forms. Other workers (among them Enneking 1948) believe that the cartilage develops from different cells from those which give rise to bone. There is also to be considered the widely held opinion (Urist and McLean 1941) that cartilage formation in the course of bone repair is a reaction to mechanical stressing, such as that resulting from imperfect immobilisation of the fragments. It was felt nevertheless that ischaemia might have some part to play in the genesis of cartilaginous callus, and so it was decided to study bone repair in the cranial vault under conditions in which the blood supply to the fracture site was greatly reduced. The cranial vault was chosen because cartilage almost never appears there during fracture repair (Pritchard 1946), and because the rigidity of the skull minimises the mechanical factor.

The method chosen was to make a number of incisions right through the pericranium, skull and dura mater, in order to restrict the blood supply to the area, and, if necessary, to scrape the periosteum from the bone as well. Very young rats were used to take advantage of the more rapid and vigorous cellular responses of immature animals, for it was believed that the presence or absence of cartilage might well turn on the outcome of the race between cellular proliferation and revascularisation, as Ham (1930) originally suggested. The results were to be studied histologically with and without prior injection of the blood vessels with indian ink.

MATERIAL AND METHODS

A total of 102 rats between three and thirty-four days old were operated upon, of which eighty-six survived, and of these the skulls of sixty-seven were sectioned. Under ether anaesthesia a parasagittal incision was made through the scalp, and the skull vault was then incised with a scalpel. To begin with (Group A), two longitudinal cuts and a connecting transverse incision were made through the left parietal bone and underlying dura mater. In a later series (Group B), the periosteum over the left parietal bone was scraped away before similar incisions were made. Finally, and this applied to most of the animals operated upon (Group C), the periosteum was scraped as before and then four incisions were made, two running longitudinally in the left parietal, one longitudinally in the right parietal, and then one transversely connecting the three previous incisions (Fig. 1).

Most of the animals were killed three to thirty-six days after the operation, and their skulls fixed in Bouin's fluid and sectioned in paraffin. Twenty-four of the animals, however, at the time of killing were deeply anaesthetised with ether, and while the heart was still contracting, a fine glass cannula was introduced into the left ventricle and a dilute solution of indian ink (1 : 3 in distilled water) slowly run in. After some hours the whole animal was fixed in 10 per cent formalin. The head was then removed and cleared as a whole mount or

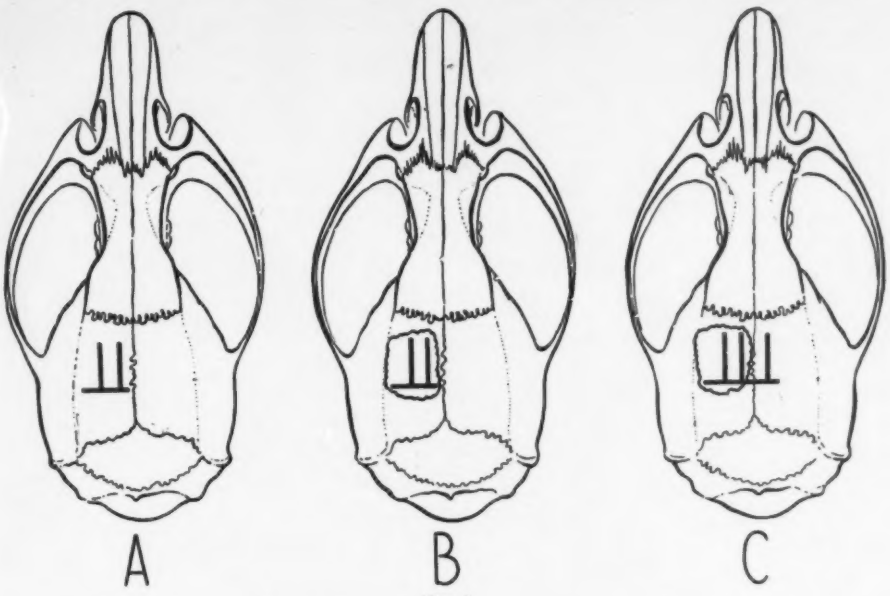

FIG. 1
Diagram showing incisions and area of scraped periosteum in Groups A, B and C.

else embedded in celloidin and cut at 80–120μ. Sections were usually lightly stained with haematoxylin and eosin or Weigert's haematoxylin and van Gieson, and counterstained with toluidine blue to show up any cartilage that might have formed.

TABLE I

FREQUENCY OF CARTILAGE FORMATION IN GROUP C.
Animals less than seven days old at the time of operation

Days after operation	Cartilage found	Number of animals
3	0	3
4–6	1	9
7–9	7	15
10–12	9	14
13–15	1	7
16–18	1	2
	19	50

RESULTS

General—None of the five animals which were recovered and sectioned from group A showed any cartilage at the fracture sites when examined histologically ten to twenty days after operation, but one of the four animals recovered from group B did show some cartilage seven days after fracture.

None of the eight animals in group C which were operated on after the first week of life showed any cartilage; but nineteen of the fifty animals studied which were operated on during the first week did show cartilage. The relative frequency of cartilage production in this last mentioned group, according to the time elapsed since operation, is shown in Table I.

It will be seen that cartilage was found with any frequency only between seven and twelve days after fracture. This may well be because, before seven days, callus differentiation is not sufficiently advanced to show cartilage formation, whereas after twelve days any cartilage formed earlier may have been replaced by endochondral bone. This is supported by the time-course of cartilage formation and replacement in fracture repair of rat long bones (Pritchard and Ruzicka 1950).

To sum up: about half of the animals operated upon in the first week of life, and in which the interference with the blood supply was most drastic, showed cartilage formation when examined seven to twelve days later. Less severe restriction of the blood supply, and operations on older animals, did not usually lead to cartilage formation.

Histology—The repair of single linear incised fractures of the rat's skull vault has been studied by Pritchard (1946). By twelve days osteoblast-covered trabeculae of new bone were to be

FIG. 2

Ischaemic fracture eleven days after operation. Note cartilage cells capping bony callus. (Weigert's haematoxylin, van Gieson and toluidine blue, ×200.)

seen surrounding the old bone at the fracture site, but, with a single exception, no cartilage was ever found.

In the present series, however, twenty examples of cartilage formation at one or other of the fracture sites (usually the central one of the three longitudinal incisions) were observed. In most instances the cartilage projected into the fracture gap from the bone edges, and in some cases extended right across the fracture line to give cartilaginous union. In a few cases the cartilage was present a little way distal to the fracture, and in two cases bony union had occurred and there was an island of cartilage cells in the midst of the bridging bone.

Figure 2 shows the most usual appearances. New bone, arising beneath the fibrous periosteum and projecting towards or into the fracture gap, is capped with a mass of cartilage cells. The pleomorphic, hypertrophic character of the cartilage cells is clearly shown in Figure 3. The same figure also shows the way in which the more centrally placed, and largest, cartilage cells grade on the one hand into smaller cartilage cells and then into osteocytes and

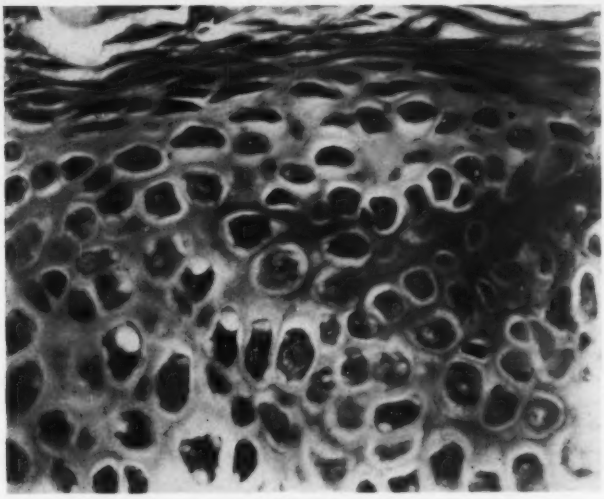

FIG. 3

Ischaemic fracture twelve days after operation. Note gradation of cartilage cells into bone cells on the right and into fibroblasts above. (Weigert's haematoxylin and van Gieson, ×420.)

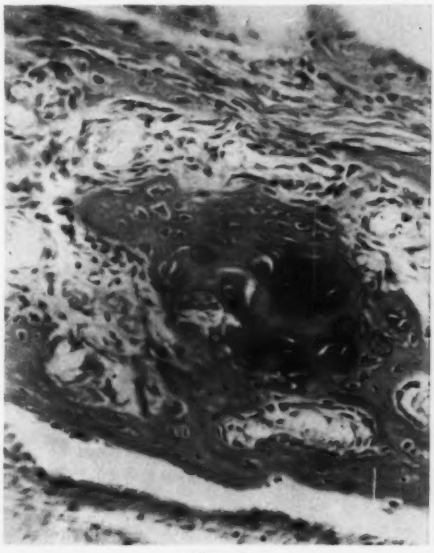

FIG. 4

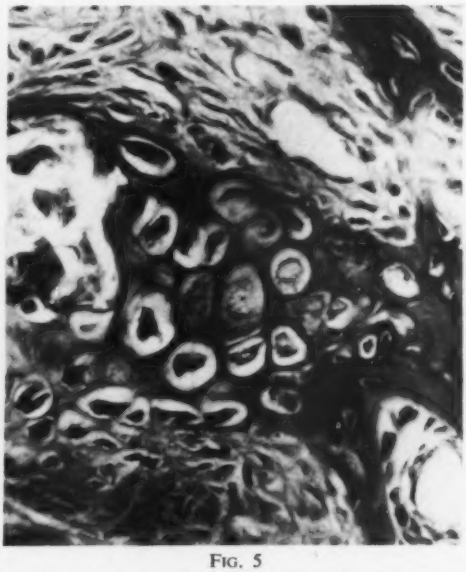

FIG. 5

Figure 4—Ischaemic fracture eleven days after operation. Note nest of cartilage cells in the midst of the bony callus. (Weigert's haematoxylin, van Gieson and toluidine blue, ×200.) Figure 5—Ischaemic fracture twelve days after operation. Note gradation of cartilage cells into bone cells. (Weigert's haematoxylin, van Gieson and toluidine blue, ×420.)

osteoblasts, while on the other hand they grade into pro-cartilage cells and then into fibroblasts.

Figures 4 and 5 show a mass of cartilage cells a little way from the fracture line, the former showing cartilage cells completely surrounded by young bone, the latter a gradation of cartilage cells into bone cells. Figure 6, on the other hand, shows cartilage cells in the midst of granulation

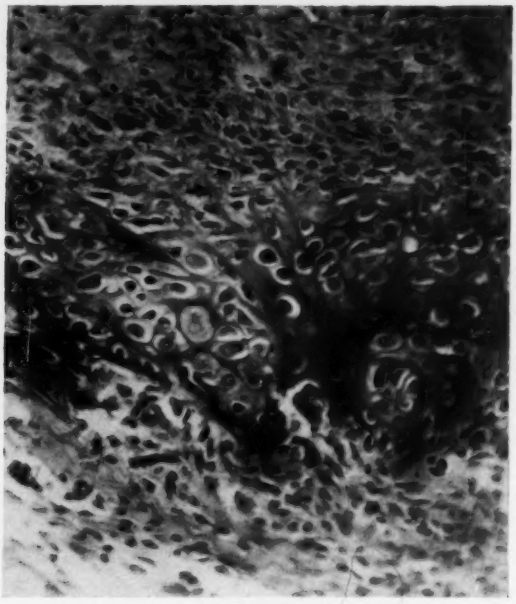

FIG. 6

Ischaemic fracture twelve days after operation. Note cartilage and bone in the granulation tissue. (Weigert's haematoxylin, van Gieson and toluidine blue, ×200.)

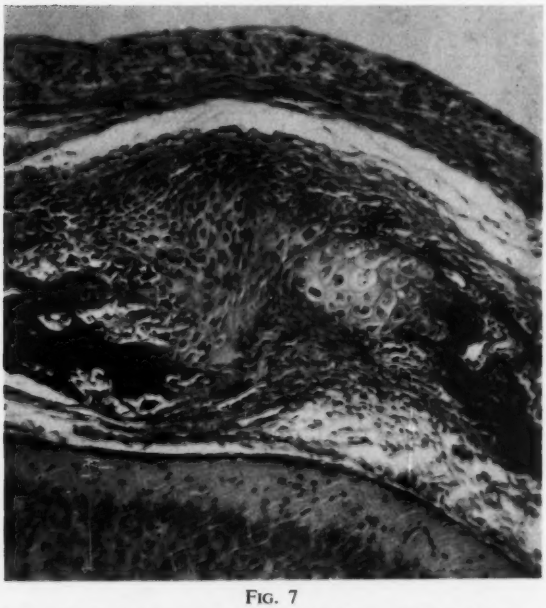

FIG. 7

Ischaemic fracture seven days after operation. Note cartilage on right, pro-cartilage on left, indicating impending cartilaginous union. (Weigert's haematoxylin, van Gieson and toluidine blue, ×100.)

tissue and not in contact with the periosteal new bone applied to the surface of the old bone. Here again gradations of cartilage into bone and young connective tissue are clearly seen. Impending cartilaginous union is shown in Figures 7 and 8, the latter section being stained with thionin to show the basophilic nature of the cartilage matrix.

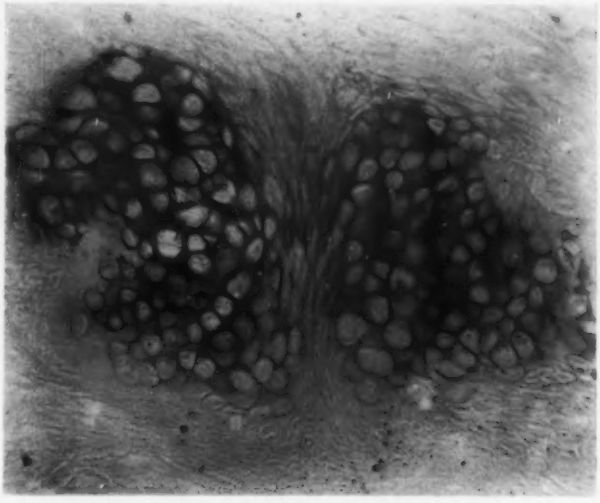

FIG. 8
Ischaemic fracture ten days after operation. Note cartilage masses about to unite. (Thionin, ×225.)

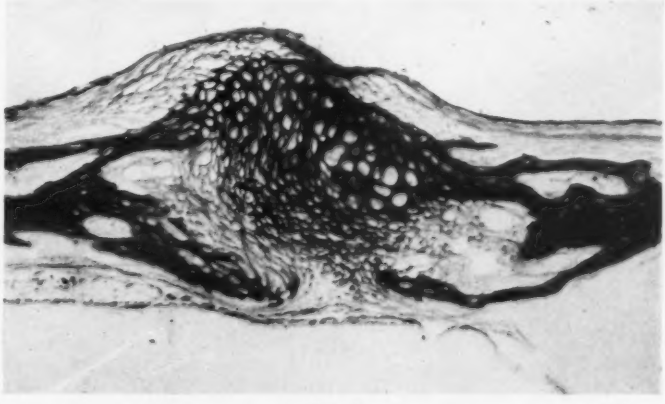

FIG. 9
Ischaemic fracture nine days after operation. Note cartilaginous union across fracture gap. (Toluidine blue, ×150.)

Actual cartilage union is illustrated in Figure 9, and bony union, with an island of cartilage, is shown in Figure 10.

It should not be supposed that every section from a given specimen showed cartilage. In most cases the cartilage was in the form of isolated nodules, and sections taken between these showed only bony callus.

Indian ink injections—The injected and cleared specimens of the skull vault, one or two days after operation, showed that relatively little ink reached the scraped and damaged area as compared with the rest of the skull. Ten days after operation, however, the vessels of the

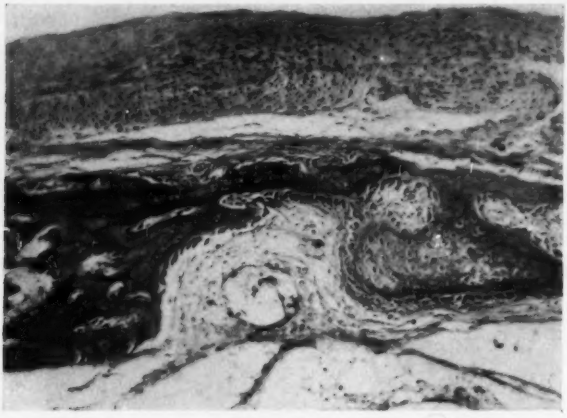

FIG. 10
Ischaemic fracture fourteen days after operation. Note bony union on pericranial side, and cartilage on the right. (Haematoxylin and eosin, ×100.)

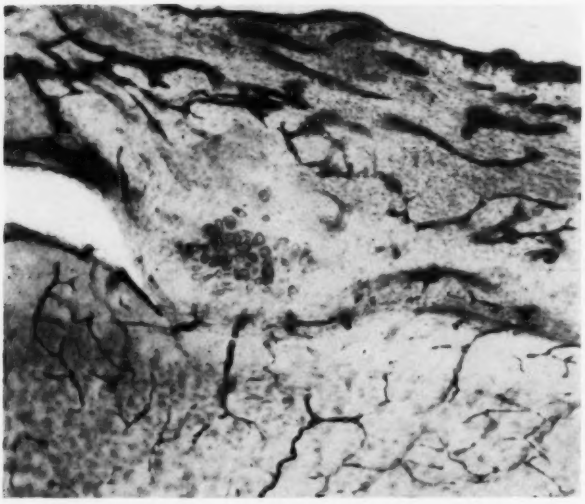

FIG. 11
Ischaemic fracture twelve days after operation. Vessels injected with indian ink. Note avascular island of cartilage. (Haematoxylin, eosin and toluidine blue, ×100.)

damaged area were well filled, indicating extensive revascularisation. Sections from injected material nevertheless brought out the fact that areas of cartilage were conspicuously free from injected vessels as compared with the new bone in the neighbourhood (Fig. 11).

CONCLUSIONS AND DISCUSSION

These experiments have shown that it is indeed possible to induce cartilage formation in the course of bone repair in the skull vault provided the animal is very young, the damage is extensive and the fracture site is examined between seven and twelve days after injury. That ischaemia is the causal factor in such cartilage production is probable from the injection studies, from the fact that single incised fractures of the skull vault very seldom show cartilage, and from the rigidity of the skull, which eliminates mechanical determinants such as shearing stresses. The fact that cartilage was produced only in very young animals, and then only when the damage was extensive, supports the view that the rapidity of cell proliferation in relation to the speed of revascularisation is a decisive factor. Restriction of cartilage to the second week after fracture is easily explained by the normal lag in matrix deposition in bone repair, and the inevitable bony replacement of any cartilage formed. The fact that the cartilage was of the secondary, hypertrophic type, and was always closely associated with new bone, without a clear line of demarcation between the cells or matrices of the two tissues, confirms Ham's view that both tissues have a common cellular origin, a hypothesis that is supported by tissue-culture studies (Fell 1933). Ham's view that ischaemia in fracture repair induces rapidly proliferating osteogenic cells to form cartilage instead of bone is thus fully supported by these experimental findings.

However, it must not be inferred from this that mechanical factors play no part in the genesis of cartilage in bone repair, for the hypothesis that pressure, and particularly shearing, stresses stimulate cartilage formation is well attested. All that is claimed here is that ischaemia is also a factor. In fact it seems probable that the two factors are closely related, for mechanical stresses may well disrupt existing blood vessels, or prevent the ingrowth of new vessels, and so produce and maintain a stage of ischaemia.

Such considerations may also explain secondary cartilage formation in the course of the normal development of some membrane bones, particularly at sutures (Pritchard, Scott and Girgis 1956), and at the extremities of bony projections (Dixon 1953). The tissues there may well be exposed to pressure stresses, and so be subject to periods of temporary ischaemia, the osteogenic cells being induced thereby to produce cartilage instead of bone.

SUMMARY

Cartilage formation was provoked in the skull vault of the young rat by making multiple incisions, and scraping the periosteum to reduce the blood supply to the injured area. The hypothesis that ischaemia induces osteogenic cells to produce cartilage in the course of fracture repair thus receives experimental support.

We should like to thank the Northern Ireland Hospitals Authority for a generous grant towards the cost of this work.

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MUSCLE ACTION, BONE RAREFACTION AND BONE FORMATION

An Experimental Study

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We regard post-traumatic osteoporosis as a trabecular rarefaction of bone occurring after injury which is detectable by radiographic examination and shows a characteristic histological picture. It has been outside the scope of this study to investigate the changes in the mineral content of rarefied bone caused by defective matrix formation (Albright 1947), a process usually referred to as decalcification (Cooke 1955).

The first reference to post-traumatic bone rarefaction or osteoporosis is that of von Volkmann (1882), who used the term post-traumatic osteitis. Then Espin (1897), Destot (1898) and Sudeck (1900, 1902) described the bone rarefaction following inflammation and injury as part of a syndrome of joint stiffness, pain, oedema, muscular atrophy and changes in skin, hair and nails. This syndrome is known in British literature as an acute reflex bone atrophy, or " Sudeck's disease." Bone rarefaction is thus only one, although perhaps the most important, of the pathological changes observed in Sudeck's syndrome.

Many hypotheses have been put forward to explain the nature and mechanism of bone rarefaction. Among them, those which attribute bone removal to immobilisation have gathered many supporters (Grey and Carr 1915, Pottorf 1916, Allison and Brooks 1921; Deitrick, Whedon and Shorr 1948, Stevenson 1952). That the compression force of weight bearing is a factor in promoting bone formation was first recognised by Ward (1838) but this did not

TABLE I

ANALYSIS OF THE EXPERIMENTS

Nature of experiment	Number
Tenotomy of tendo calcaneus	40
Plaster-of-Paris immobilisation alone . . . . . (Eight of these were also used to study bone formation after immobilisation had been discontinued)	22
Plaster-of-Paris and faradic stimulation	4
Fracture of tibia with wire circlage and plaster-of-Paris .	14
Resection of peritendinous tissue round the tendo calcaneus	2
Total .	82

gain medical recognition until nearly thirty years later when the Swiss engineer Culmann and the anatomist Meyer (1867) published their work on which the trajectorial theory is based. Since that time attention has been paid to the process of trabecular orientation and bone formation, but much less interest has been shown in the mechanism of bone removal which accompanies the suppression of stresses and strains through bone, and particularly those arising from muscular action.

* Scholar of the Swiss National Fund for Research.

Nevertheless, attempts have been made to reproduce experimentally Sudeck's syndrome in laboratory animals, notably by Brandes (1914), who attributed bone atrophy after division of the tendo calcaneus and encasement of the limb of the rabbit in plaster to "disuse." Herfarth (1924) considered that bone rarefaction after excision of the peritendinous tissue of the calcaneal tendon in rabbits depended upon the neurectomy that he believed the procedure entails. No worker seems to have been able to produce the complex clinical picture of Sudeck's disease in laboratory animals, but some have succeeded in causing bone rarefaction. In spite of this, information is still lacking on the real cause of bone rarefaction from "disuse" or immobilisation.

The present experimental work was undertaken to study the factors responsible for bone removal in immobilised limbs, and to collect data on the mechanism of bone rarefaction. Particular attention has been paid to changes of the vascular pattern accompanying the process of bone resorption.*

EXPERIMENTAL WORK

Eighty-two rabbits of both sexes, varying from three to twelve months of age, were used. The experiments that were undertaken are summarised in Table I.

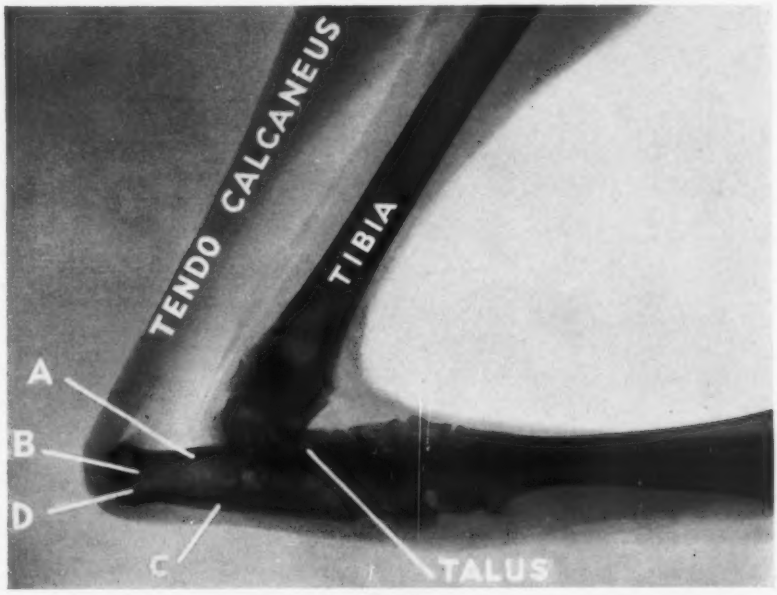

FIG. 1

Normal anatomy of a rabbit's foot. A, upper cortex; B, fan of trabeculae; C, lower cortex; D, line of the former site of the apophysial cartilage; A, B, C, D, tuber calcanei.

The bones of the foot and leg were radiographed at regular intervals. At the end of each experiment the animal was killed and the vessels of the lower extremities were injected and prepared in accordance with methods already described (Trueta, Barclay, Franklin, Daniel and Prichard 1947; Trueta and Harrison 1953).

* A preliminary report on the early phase of this research has been published with the other contributions to the Conference on Post-traumatic Osteoporosis which took place in Knokke (Belgium) in 1956 (Trueta 1956*b*), but for the most part the material collected here is new.

RESULTS

EXPERIMENT 1

Partial excision of calcaneal tendon (forty rabbits)—A piece of the right tendo calcaneus one centimetre long was excised about two centimetres proximal to the attachment of the tendon (Figs. 1 and 2); the left tendon served as a control. Simple tenotomy in a rabbit heals by fibrous union which permits good function within six to seven days. Excision of as much as one centimetre is often insufficient to prevent the cut ends of the tendon from uniting

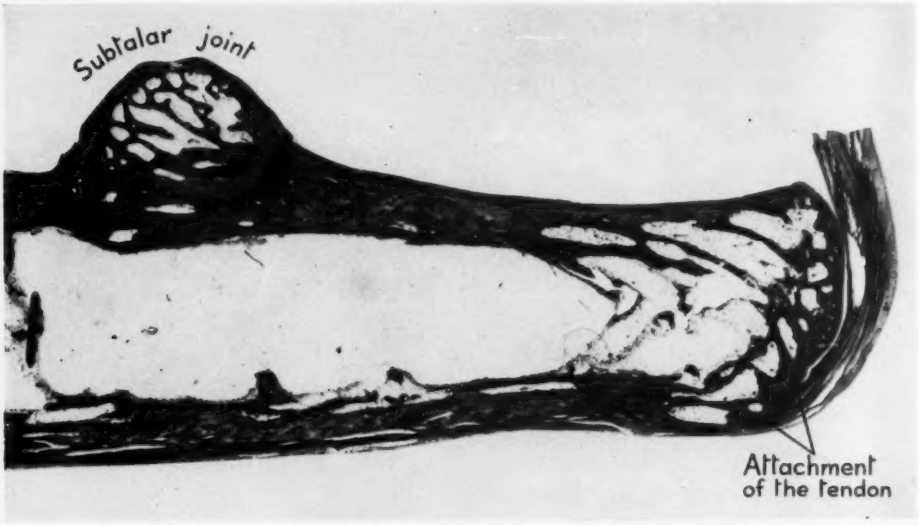

FIG. 2
Attachment of the calcaneal tendon to the calcaneum. Eighteen-month-old rabbit.

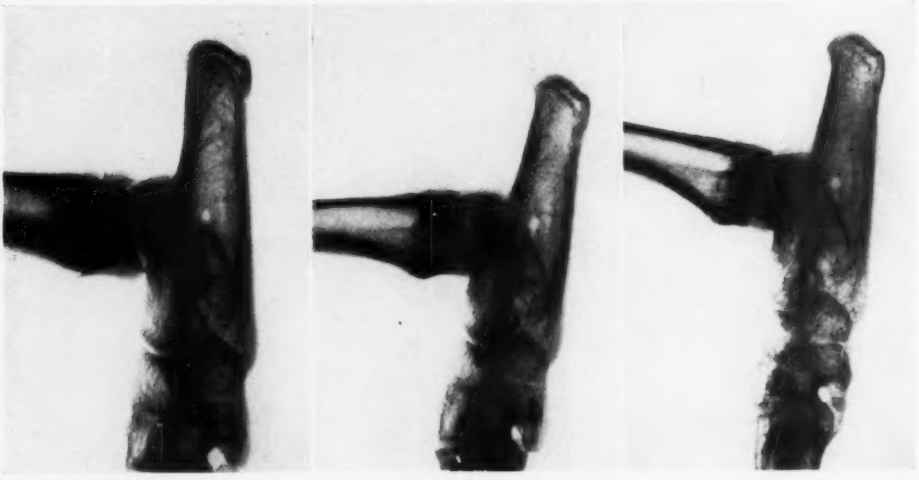

FIG. 3
Left—Radiograph of a normal rabbit's right foot. *Middle*—Three weeks after tenotomy of the calcaneal tendon. *Right*—Five weeks after tenotomy of the calcaneal tendon. Note the progress of bone rarefaction in the fan of trabeculae already well apparent after three weeks, and in the upper and lower cortices of the calcaneum and in the other bones of the foot.

by a fibrous scar. It is unusual for this scar to allow substantial function of the calf muscles, but in some cases it was necessary to excise it a fortnight after the tenotomy in order to prevent the calf muscles from regaining function. After tenotomy the animals were left free. The paw was held in dorsiflexion by the animal, and it was not used any more for jumping or taking weight.

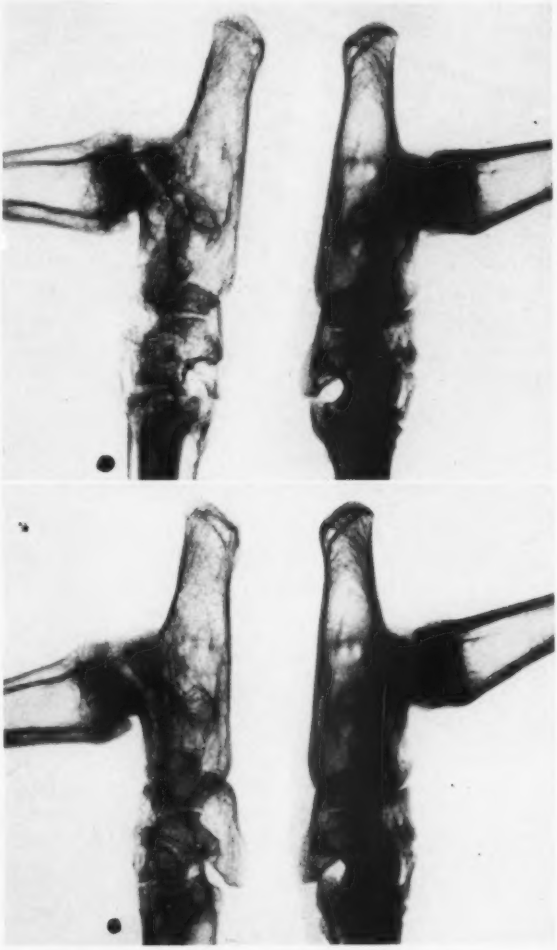

FIG. 4

Radiographs five and seven weeks after tenotomy of the calcaneal tendon in an adult rabbit of twelve months, with the normal foot shown for comparison. After five weeks no further bone rarefaction occurs. (The side operated upon is marked with a dot.)

In this experiment the animals were killed at short intervals (namely at 2, 4, 6, 8, 9, 11, 12, 13, 14, 16, 18, 20, 22, 26, 28, 33, 42, 49, 71 and 89 days after operation) in order to collect information on the successive changes taking place in the bones.

Results. *Analysis of the radiographic findings*—The first changes in the bones of the foot were just visible one week after tenotomy. They consisted in an early fading of the fan of trabeculae

in the tuber calcanei. This slight but distinct change could be seen only in the lateral radiograph. In young animals with an apophysial growth cartilage the radiographic change was visible proximal to this cartilage. Two weeks after operation increasing rarefaction in the fan of trabeculae and in the cortex of the calcaneum had occurred, a change which was more obvious after three weeks (Fig. 3). At four weeks osteoporosis in the whole tarsus was noticeable. After the fifth and sixth weeks gross rarefaction of the whole foot, including the ankle region, was present (Fig. 4).

It was repeatedly noted that, if the tenotomy failed to keep the calcaneal tendon severed, bone rarefaction decreased or even ceased altogether. A comparison of the bones of animals with the same duration of experiment, but not with an equally successful tenotomy, demonstrated this fact. It was soon possible to detect radiographically the establishment of fibrous union after tenotomy by the sudden interruption of bone rarefaction. How much the completeness of tenotomy influences the histological aspect of the bone will be shown later.

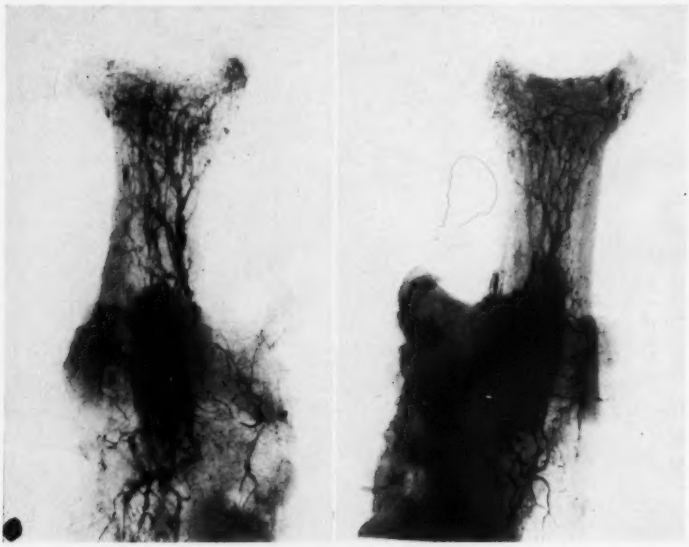

FIG. 5

Angiographs six days after calcaneal tenotomy. There is definite hypervascularisation on the side operated upon, shown at left.

Study of the angiographs—The arteries of most of the animals were injected at the end of the experiment. During the first four days after operation the vessels of the calcaneum were fewer than normal and less well filled, but from the sixth day onwards to the end of the fourth week more and better filled vessels appeared on the side of operation than on the control side (Figs. 5 to 7). After the fifth week the vessels on the side of the tenotomy became fewer and smaller (Fig. 8).

Thus, the short initial period of hypovascularity was followed by a longer period of greatly increased vascularisation, which was coincidental with bone rarefaction, persisting until the rarefaction disappeared. The vascularisation decreased after the fifth week, apparently to adapt itself to the demands of the hypotrophic bone. There seemed to be little doubt that the hypervascularisation did not start immediately after the operation; the thick celloidin bone sections confirmed this finding repeatedly (Fig. 9), and in the four animals that we injected within the first four days after tenotomy the same decrease in vascularity was always found.

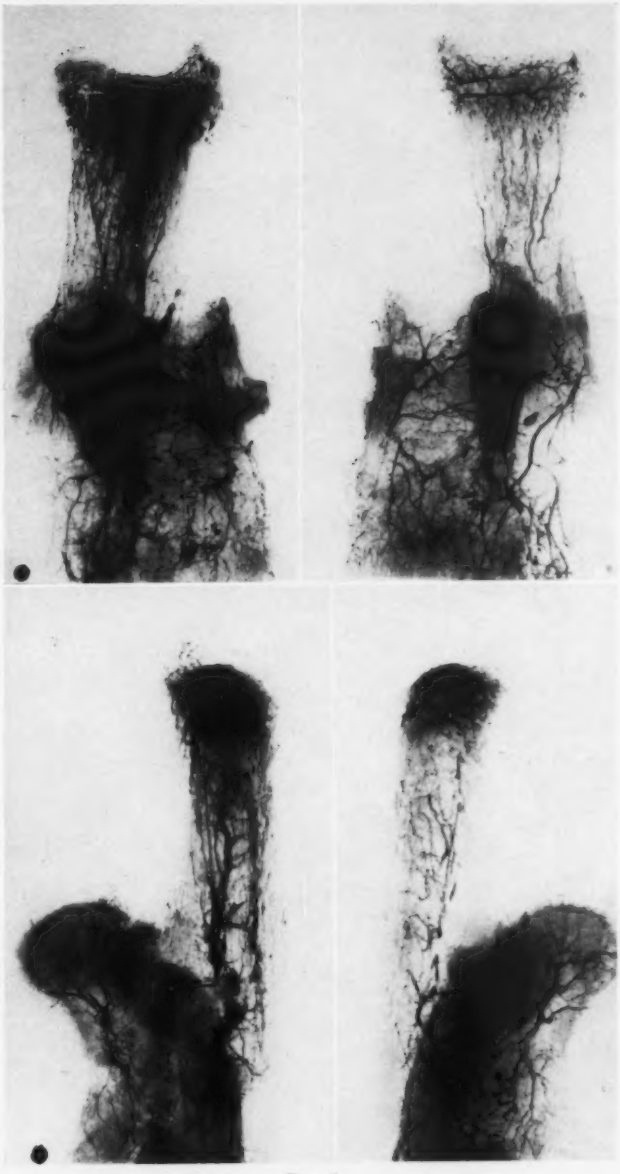

FIG. 6

Antero-posterior and lateral angiographs eight days after calcaneal tenotomy. There is marked hypervascularisation on the side operated upon, shown at left of each pair.

FIG. 7

Angiographs twenty-eight days after calcaneal tenotomy. There is still a slight hypervascularisation on the side operated upon, shown at left.

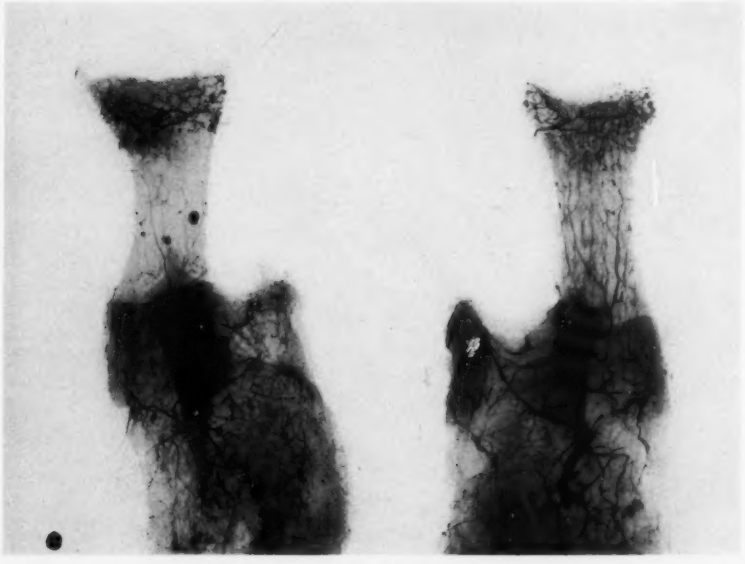

FIG. 8

Angiograph six weeks after tenotomy. The picture has changed: there is now hypovascularisation on the side operated upon. The vascularisation accords with the amount of bone present after bone rarefaction has taken place.

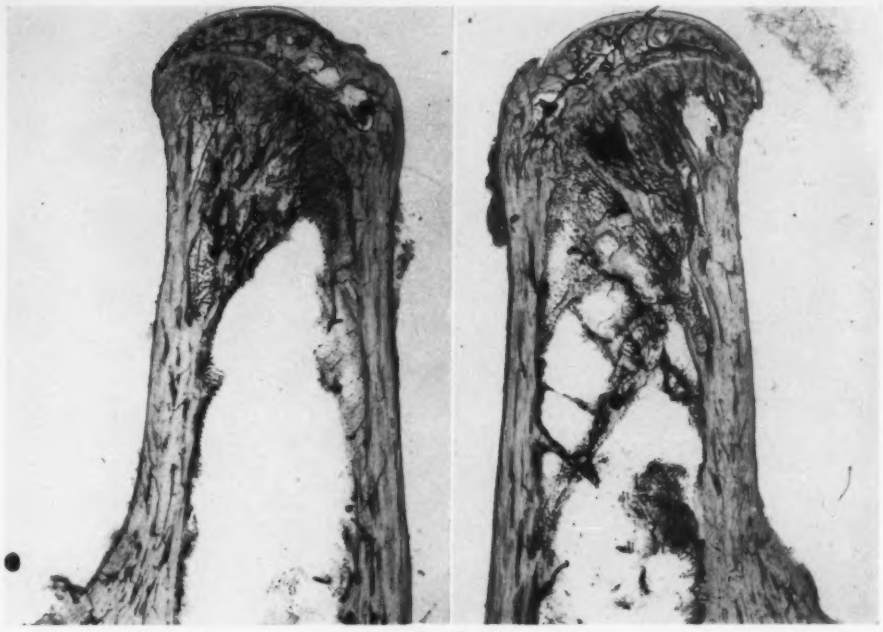

FIG. 9

Vascular picture four days after calcaneal tenotomy. Thick celloidin section (300μ), through calcaneum, unstained. Injected with Berlin blue and micropaque. The side operated upon (*left*) shows less well injected vessels.

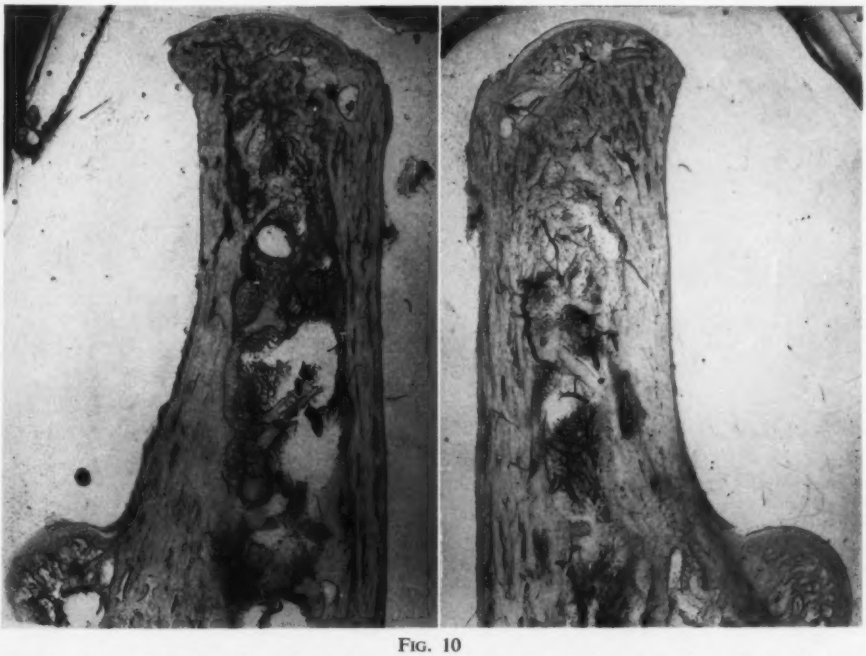

FIG. 10

Vascular picture eight days after calcaneal tenotomy (*left*). Same technique as in Figure 9. Section only 150μ thick. Considerable hypervascularisation on the side operated upon. (Same rabbit as shown in Figure 6.)

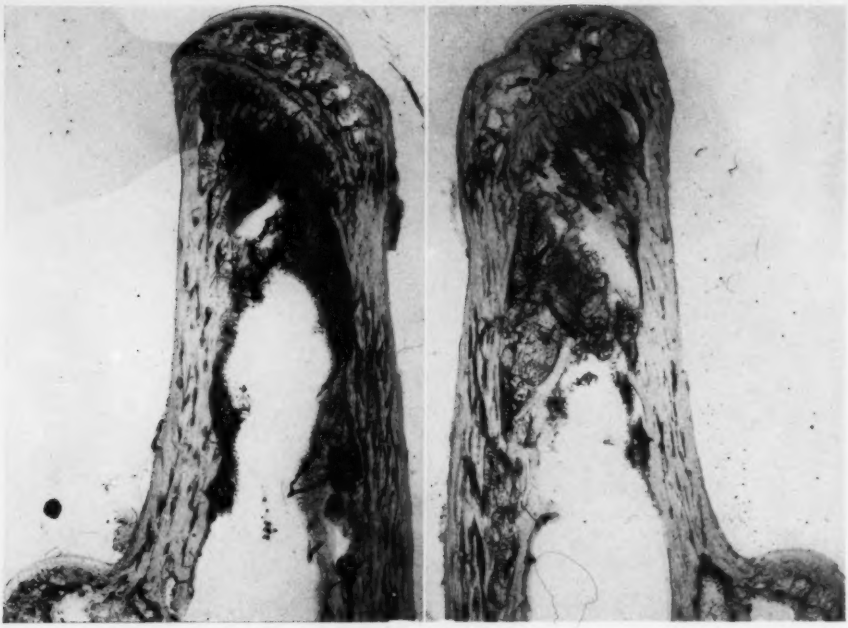

FIG. 11

Vascular picture fourteen days after calcaneal tenotomy. Same technique as in Figure 9. Injection with Berlin blue only. There is marked hypervascularisation on the side of the tenotomy (*left*).

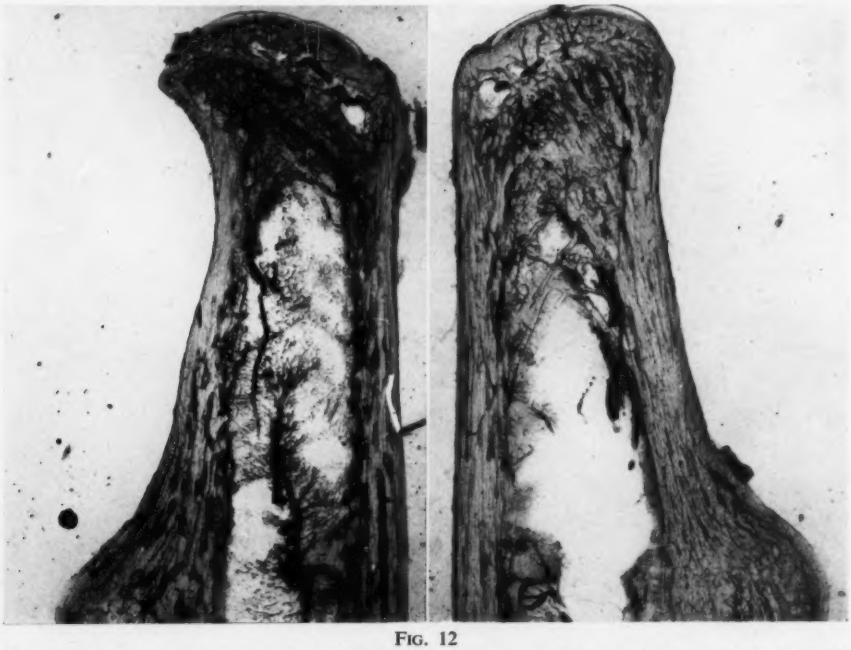

FIG. 12

Vascular picture twenty-two days after calcaneal tenotomy. Same technique as in Figure 9. Considerable hypervascularisation on the side operated upon (*left*).

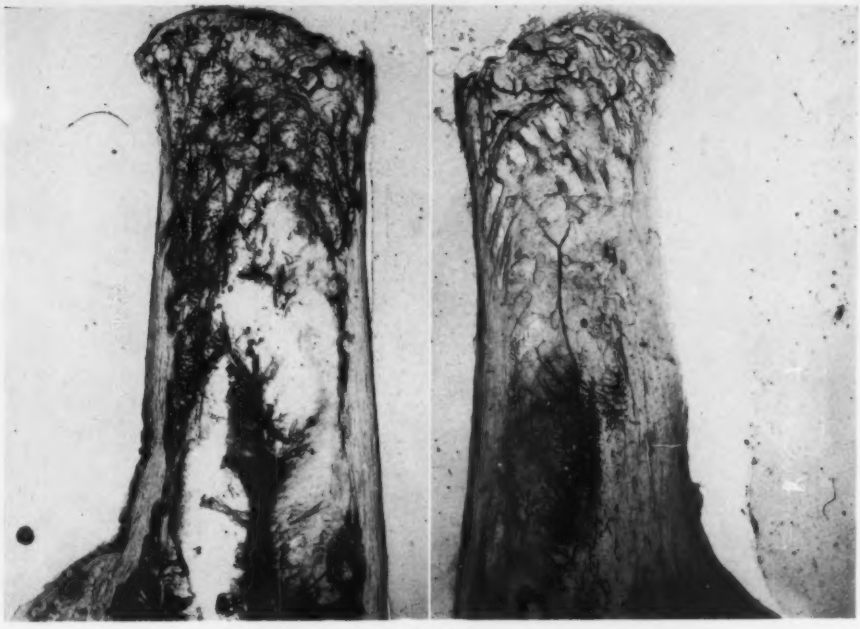

FIG. 13

Vascular picture twenty-eight days after calcaneal tenotomy. Same technique as in Figure 9. There is still increased vascularisation on the side operated upon (*left*). (Same rabbit as shown in Figure 7.)

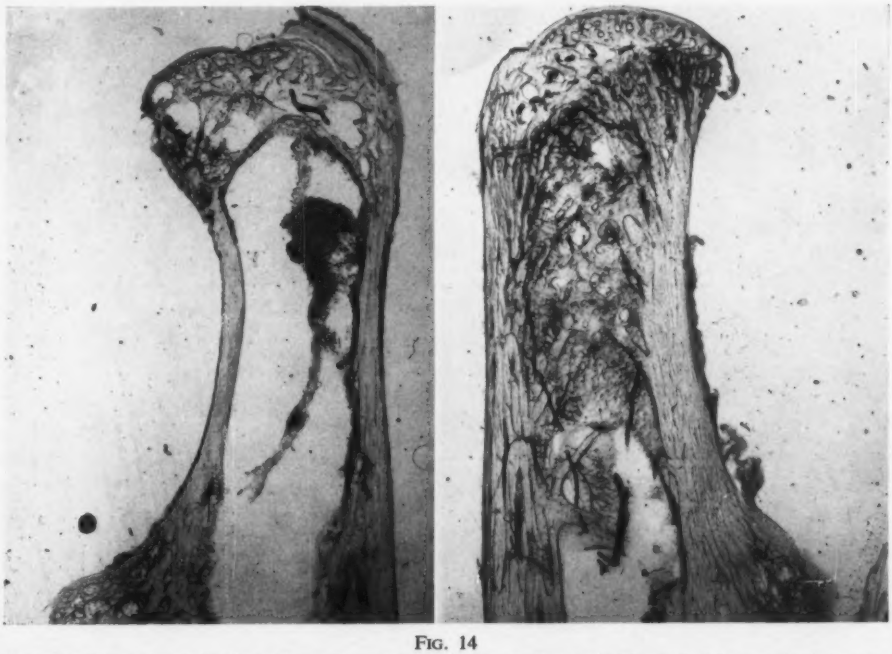

FIG. 14

Vascular picture six weeks after calcaneal tenotomy. Same technique as in Figure 9. The vascularisation on the side operated upon (*left*) has now decreased according to the bone left behind after rarefaction had taken place. (Same rabbit as shown in Figure 8.)

Histology—Since the bone rarefaction after plaster immobilisation and fracture circlage was indistinguishable in the radiograph from that found after tenotomy, we limited the systematic histological investigation to the bone rarefaction after tenotomy. About 500 sections—four to eight sections for each calcaneum—were examined, the left calcaneum always serving as a control. The histology was also studied in eight animals after simple plaster immobilisation for three weeks and after various periods of remobilisation. In addition to thin sections of 12 to 15μ, we also used thick unstained sections of 150 to 300μ to investigate the behaviour of the vessels we had injected with Berlin blue (Figs. 9 to 14).

In all the bone sections the cells that are usually known as osteoblasts and osteoclasts were present (Figs. 15 to 25). We noted areas of bone formation with layers of osteoid

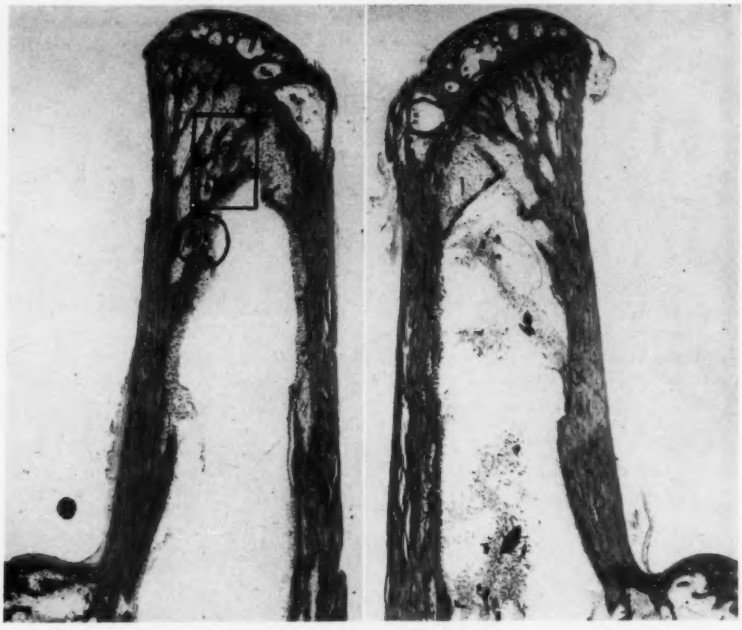

FIG. 15

Sagittal section through the calcaneum four days after calcaneal tenotomy. (Celloidin section, ×7.) There is no difference between the side operated upon (*left*) and the control side. The area squared is shown in Figure 16. The area marked with a circle is shown in Figure 17.

tissue and osteoblasts, and areas of bone rarefaction with osteoclasts, in all the sections both on the side of the operation and on the control side, apparently confirming the role attributed to these cells. These findings agree with the generally accepted opinion that normal bone continuously undergoes both removal and new formation, both processes being especially intensive in the zone of ossification in the metaphysis of growing bone. Whereas we observed a relatively quiescent picture of bone trabeculae in the calcaneum of the control side, the behaviour of the bone on the side of the experiment was quite different. The picture in Figure 14 shows how bone had disappeared during the six weeks after tenotomy, the calcaneum presenting nothing but a feeble frame at the end of that time. In all the animals in which five to six weeks after tenotomy only a thin reticulum was left, the picture observed was like those shown in Figures 14, 26 and 27. These changes could be observed from the fourth day after operation until the end of the fourth week, and consisted of a considerable hypervascularity

and thinned trabeculae covered by cells which in well stained sections are usually considered to be osteoclasts by their acidophilic protoplasma (Fig. 23). One is, of course, inclined to interpret this hypervascularity, the presence of many osteoclasts and the picture of disturbed trabeculae as a battlefield of bone rarefaction and to make hyperaemia responsible for the disappearance of bone (Figs. 19 to 21). Our opinion on these findings will be given later. An important observation must be advanced here, namely that we could see signs of osteoblastic

FIG. 16

Field of bone rarefaction four days after calcaneal tenotomy. (Celloidin section, 12μ. Injection with Berlin blue and micropaque, ×100.) Numerous osteoclasts are seen. This picture is enlarged from that shown in Figure 15.

activity at a time when the hypervascularity was not yet present—that is, four days after the tenotomy.

This histological investigation could add nothing new on the assumed function of the osteoclasts, which still remains obscure. Nevertheless, their close relationship to absorbing bone and to the cellular elements of the vessel wall is striking.

After the second week from tenotomy we often came across peculiarly shaped giant cells resembling osteoclasts situated far away from the bone (Fig. 25).

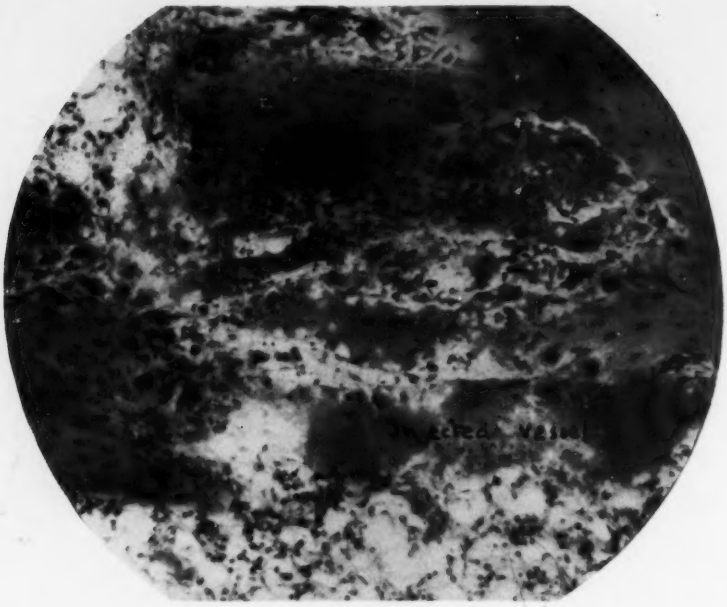

FIG. 17

Field of bone rarefaction four days after tenotomy. Same bone and same technique as in Figure 16. The area is marked with a circle in Figure 15. Note the vascularisation and the numerous osteoclasts.

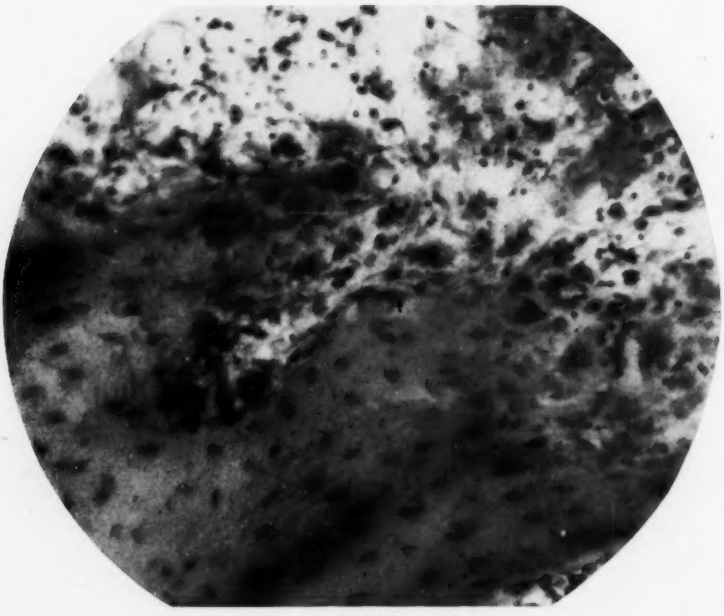

FIG. 18

Detail from Figure 17. (×200.)

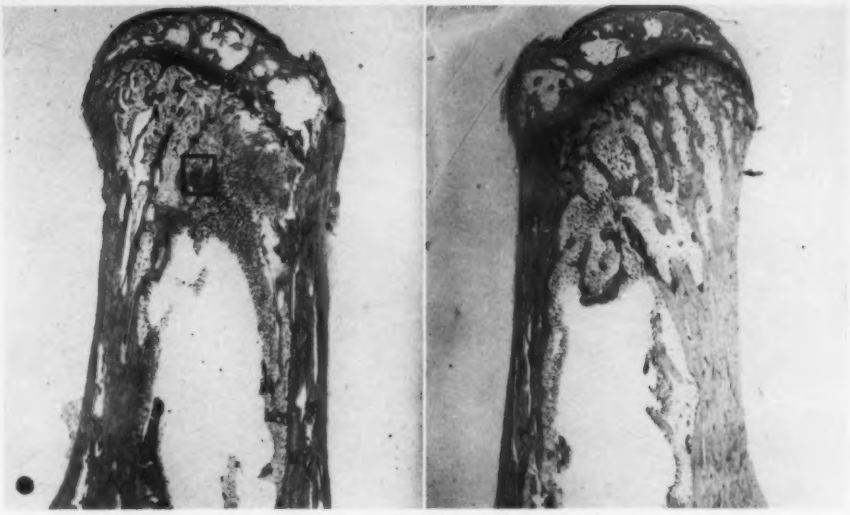

FIG. 19

Sagittal section through the calcaneum eleven days after tenotomy. Same technique as in Figure 15. Bone rarefaction is occurring on the side operated upon (*left*). Same rabbit as shown in Figure 6. The squared area is shown in Figure 20.

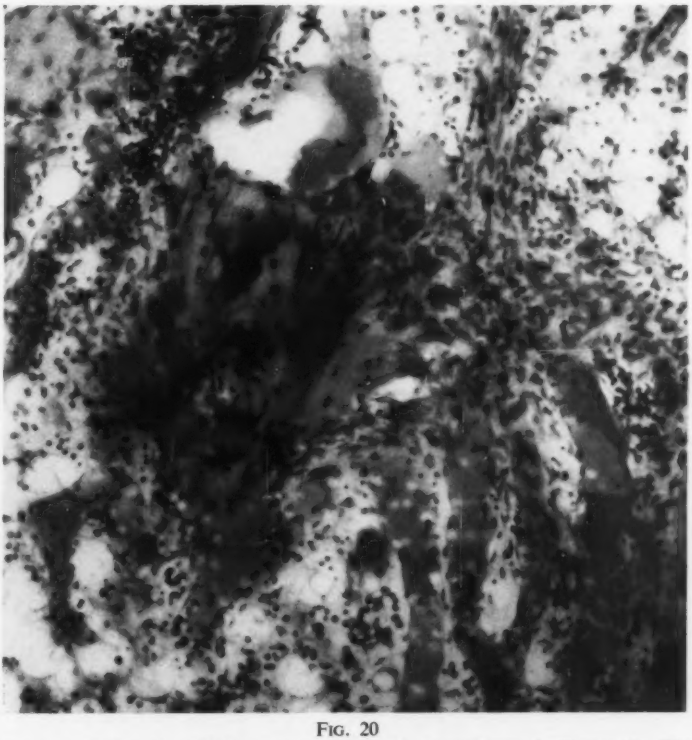

FIG. 20

Bone rarefaction in a field corresponding to the squared area in Figure 19. The injected vessels look like roads ending in a row of osteoclasts.

FIG. 21

Field of bone rarefaction at the time of the greatest vascularisation on the eleventh day after calcaneal tenotomy. Same technique as in Figure 20. Note the close contact between vessel walls and osteoclasts.

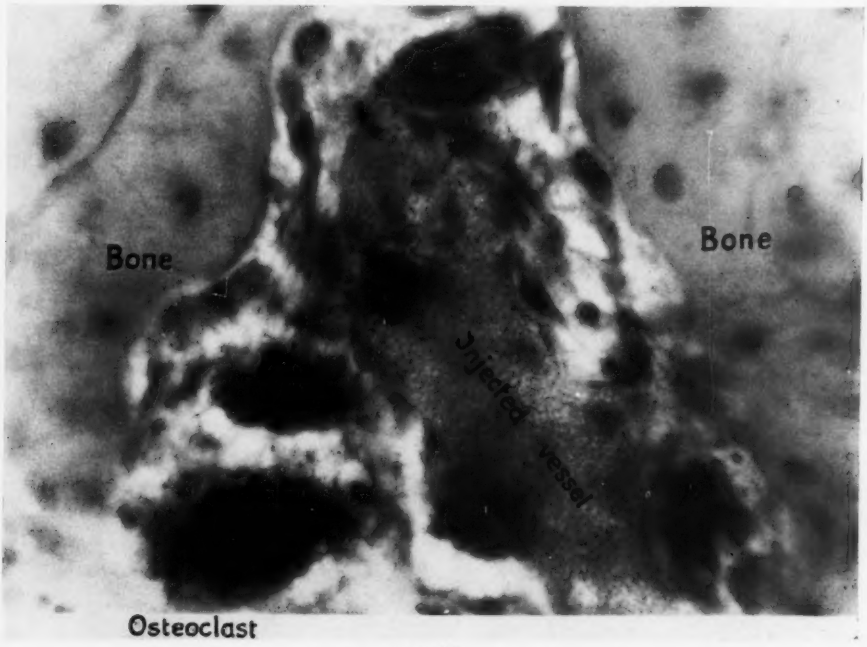

FIG. 22

Osteoclastic activity in a calcaneum two days after calcaneal tenotomy. Note the close relationship of osteoclasts, bone and vessel wall. (×300.)

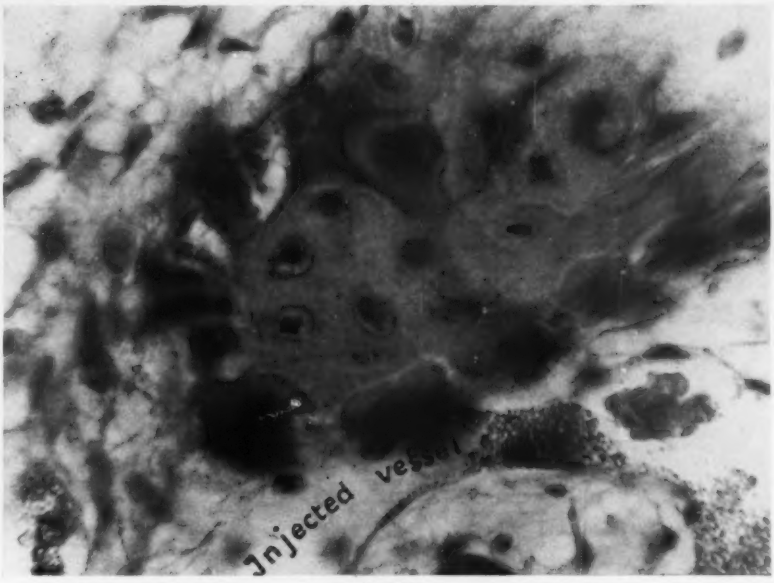

FIG. 23
Osteoclastic activity eleven days after calcaneal tenotomy. A bone trabecula completely covered by osteoclasts.

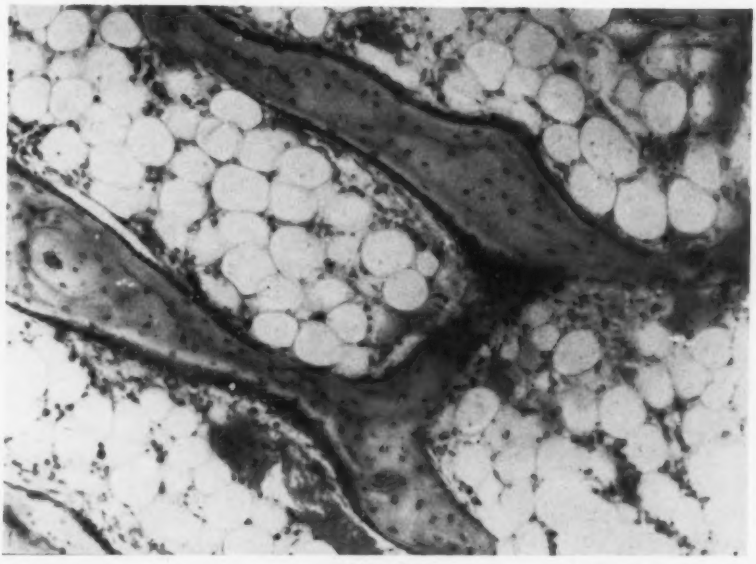

FIG. 24
Bone formation in a calcaneum twelve days after a tenotomy which had healed by fibrous union. Lines of osteoblasts are present in the periphery of the trabeculae. (Celloidin section with the same technique as in Figure 20.)

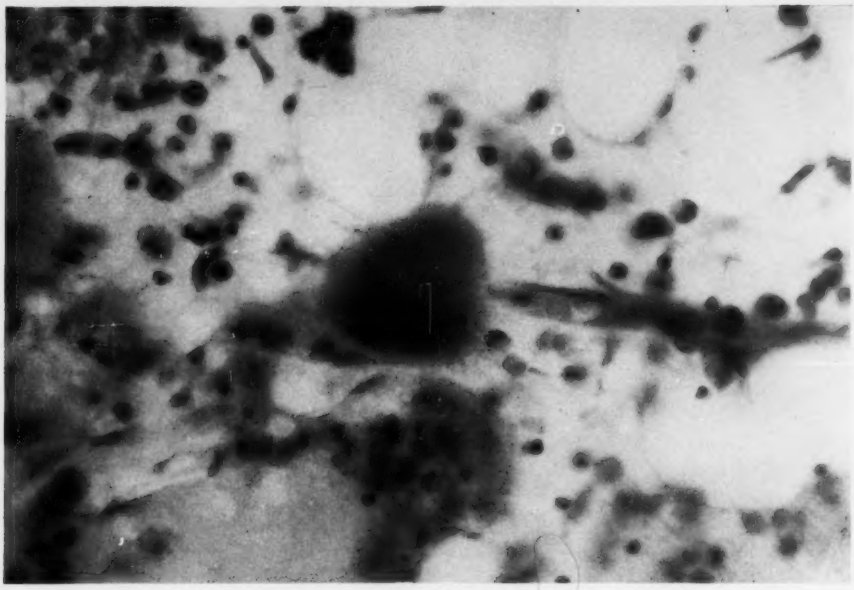

FIG. 25

Peculiar shaped giant cell, apparently an osteoclast, found very often in the bone marrow far away from bone.

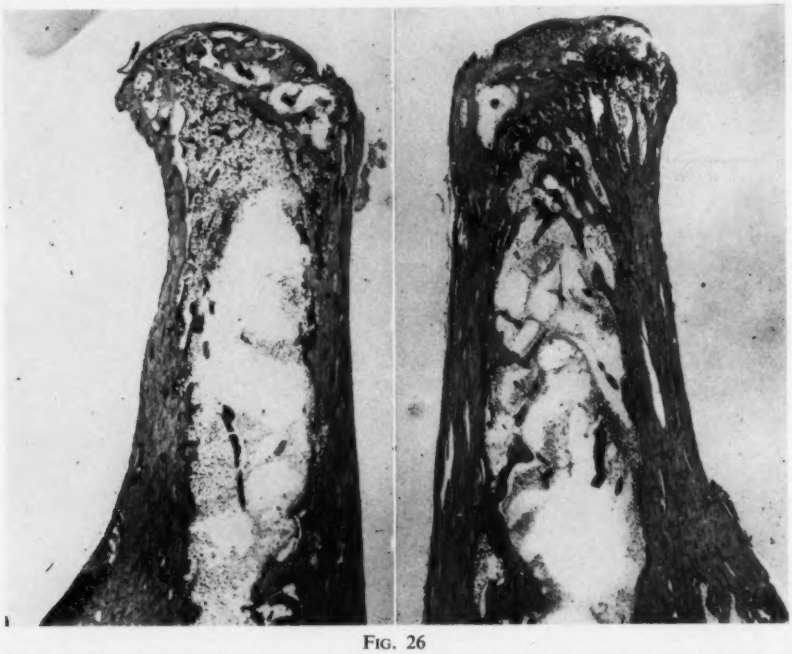

FIG. 26

Sagittal section through calcaneum twenty-two days after calcaneal tenotomy. Note the marked bone rarefaction on the side operated upon in the fan of trabeculae in the lower, and particularly in the upper, cortex. (Same animal as shown in Figure 12. Same technique as in Figure 15.)

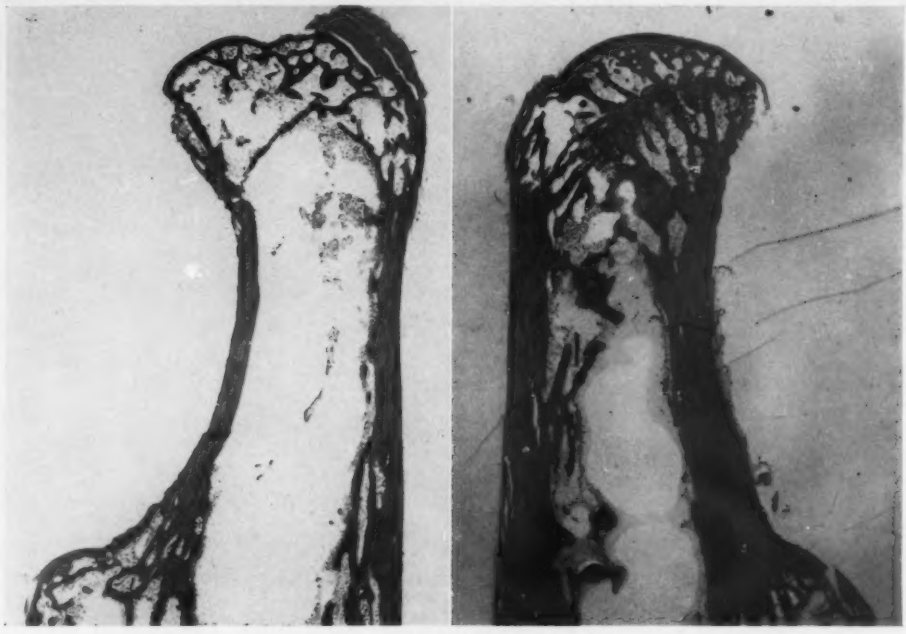

FIG. 27

Sagittal section through calcaneum six weeks after calcaneal tenotomy. There is marked bone rarefaction, the calcaneum being no more than a thin frame. The destructive process has reached its climax. (Same animal as shown in Figures 8 and 14. Same technique as in Figure 15.)

Comment—Persistent interruption of the action of the calf muscles in all the forty rabbits studied in this series caused progressive bone atrophy which was clearly established at the end of the second week. This bone resorption continued for five or six weeks, after which the bone structure remained unchanged. The large intertrabecular spaces caused by bone removal were filled by large new vessels but this increased vascularity was found to cease when the process of bone atrophy reached its final stage.

EXPERIMENT 2

To determine the part that simple immobilisation may play in causing bone atrophy the experiments described below were performed.

Immobilisation in plaster-of-Paris (twenty-two rabbits)—The right hind leg of the rabbit was immobilised by a padded plaster extending from the toes to just above the knee with the ankle at right angles or—in certain cases—in plantarflexion to relax the calf muscles. Eight animals of this series were left free after three to four weeks of plaster immobilisation, for study of the regeneration of the rarefied bone. They were killed 2, 11, 16, 21, 29, 35 and 42 days after the plaster had been removed.

Results—Immobilisation of the leg and foot in plaster caused changes in the radiographic picture (Fig. 28), in the angiographs (Fig. 29) and in the sections (Fig. 30) like those we have described after tenotomy. The sequence of bone rarefaction in the radiographs was the same as after successful tenotomy, the main rarefaction taking place within four to five weeks. We are unable to say whether the period of hypervascularisation begins immediately after plaster immobilisation or after a short delay as in tenotomy, because no animal was killed within the first week of plaster immobilisation.

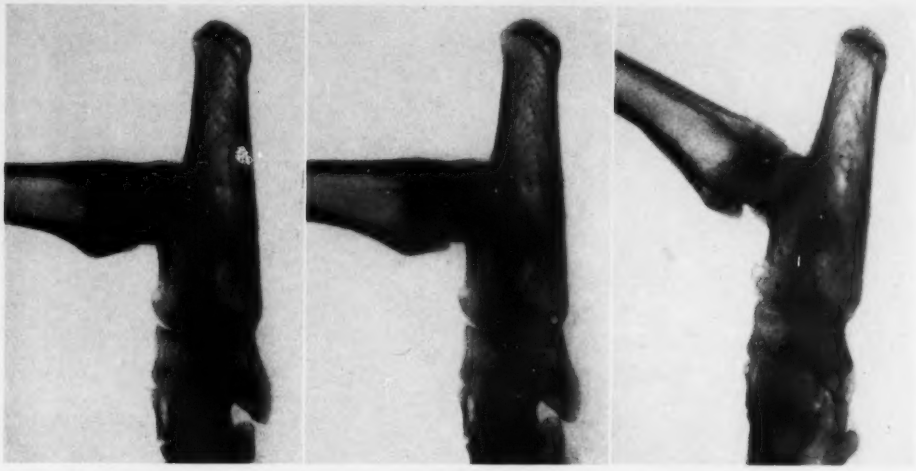

FIG. 28

Radiographs of a rabbit's right foot which was immobilised in a plaster for four weeks. The radiographs were taken before immobilisation and two and four weeks after immobilisation. The resultant bone rarefaction does not differ much from that following calcaneal tenotomy (Fig. 3).

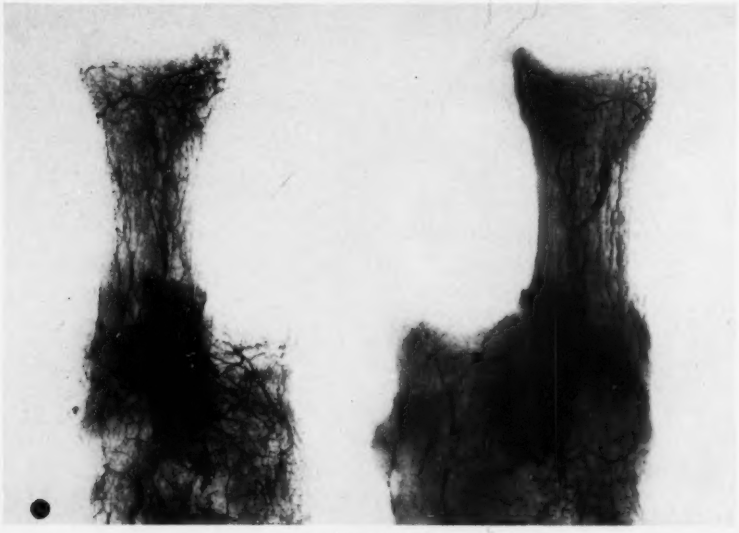

FIG. 29

Angiographs after three weeks of plaster immobilisation show some increased vascularisation on the immobilised side (*left*).

If bone rarefaction were due to lack of muscle action no great difference between the results obtained after division of the calcaneal tendon and of plaster immobilisation should be expected, because in the rabbit division of the tendo calcaneus means a very effective immobilisation of the foot and leg.

Plaster immobilisation in a position of plantarflexion caused a quicker and more intensive bone rarefaction than immobilisation in the position of 90 degrees or less (Figs. 31 and 33.)

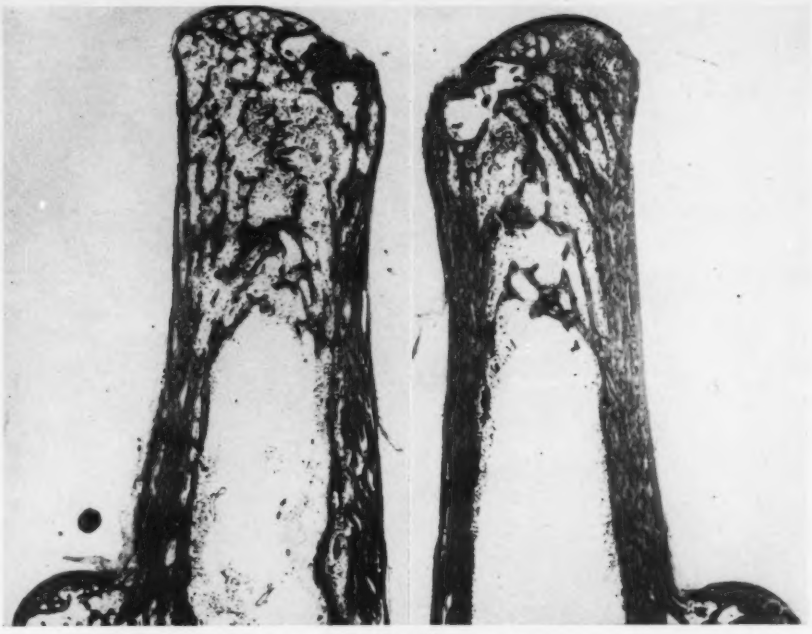

FIG. 30

Sagittal section through calcaneum after three weeks' plaster immobilisation of the right leg. Note the marked rarefaction on the side that was immobilised (*at left*). (Same animal as shown in Figure 29. Same technique as in Figure 15.)

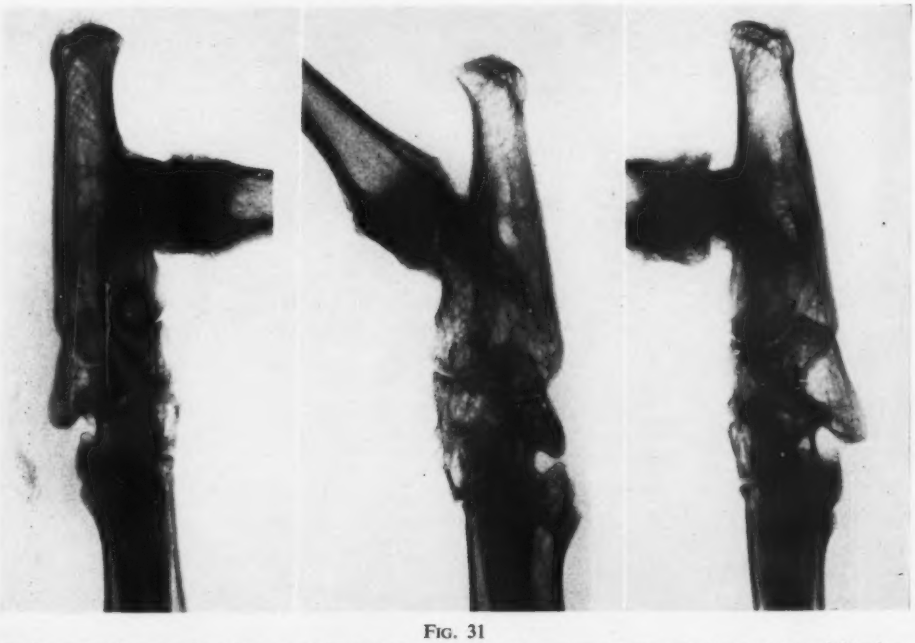

FIG. 31

Radiographs showing the influence of the position of a joint in causing osteoporosis through immobilisation. *Left*—Normal rabbit's foot. *Middle*—After four weeks' plaster immobilisation in 160 degrees of plantarflexion. *Right*—After four weeks' plaster immobilisation with the ankle joint at a right angle.

Comment—In these experiments no appreciable difference in the rate and severity of bone atrophy after simple immobilisation in plaster and after excision of part of the calcaneal tendon was found. But in animals immobilised with the foot in marked plantarflexion, by which the contractive power of the calf muscles is inhibited, both the rate and severity of bone rarefaction were much increased.

In order to study the part that muscle contraction may play in preventing bone atrophy in immobilised limbs the following further experiments were conducted.

EXPERIMENT 3

Immobilisation in plaster-of-Paris and faradic stimulation (four rabbits)—In four rabbits immobilised by plaster as in the previous experiment, a window just large enough to admit a fine electrode was cut in the plaster over the calf muscles. Through this window faradic

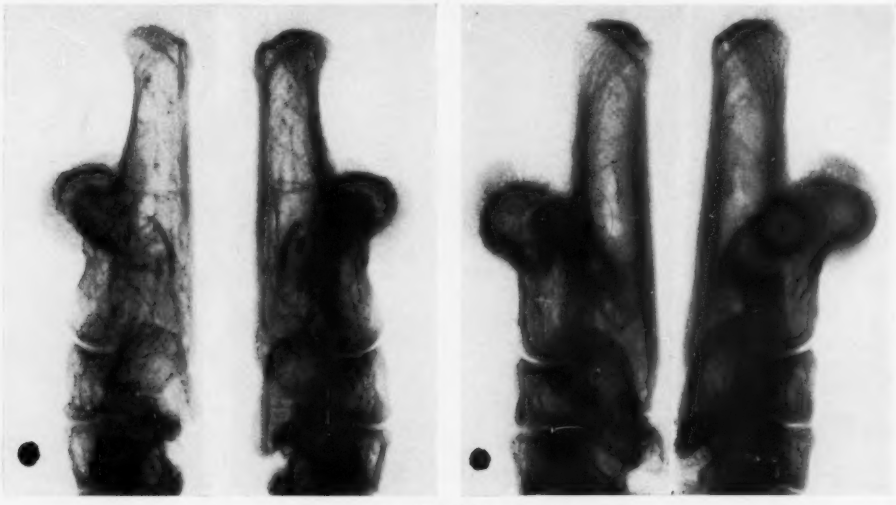

FIG. 32

The left picture shows the effect of four weeks' plaster immobilisation of the right hind leg and the right picture the effect of immobilisation and faradic stimulation of calf muscles over four weeks. The bone rarefaction was partly prevented by the faradic stimulation of the calf muscles.

stimulation was applied twice a day in two animals and eight times a day in the other two animals. Each session consisted of about a hundred isometric contractions of the calf muscles. The experiment was discontinued after four weeks because we knew from other experiments that plaster immobilisation of this duration produces considerable bone rarefaction in the rabbit. As controls we used both the left normal hind limbs and other animals immobilised in plaster which did not receive faradic stimulation, because both hind legs of a rabbit cannot be immobilised without serious impairment of its health.

Results—In the rabbits stimulated twice daily after immobilisation in plaster no significant difference was shown from the bone rarefaction of control animals immobilised without faradic stimulation. The two animals that were stimulated eight times a day showed after three weeks only slight bone rarefaction limited to the fan of trabeculae in the tuber calcanei. After four weeks bone rarefaction had somewhat increased (Fig. 32) but without reaching the severity of that observed in comparable animals immobilised for the same period.

Comment—Faradic stimulation of immobilised calf muscles appeared to have a preventive action on bone rarefaction in the foot. It was obvious that intermittent faradic stimulation

could not produce the same stresses in the bones as those of the normal activity of the laboratory animal. It had not been expected that a complete hindrance of bone rarefaction by intermittent isometric muscle contraction could be obtained, but it was interesting that a relatively small number of muscle contractions were able to maintain bone structure within the boundaries of normality in the few animals in which it was tried.

EXPERIMENT 4

Severe trauma is considered directly responsible for causing bone rarefaction, perhaps through a vaso-motor disturbance, but we are not aware of any evidence to suggest that it is not the muscular inhibition after severe injuries affecting the bones that causes bone resorption. In the next series of experiments we tried to find out whether injury in itself may aggravate the osteoporosis of immobilisation.

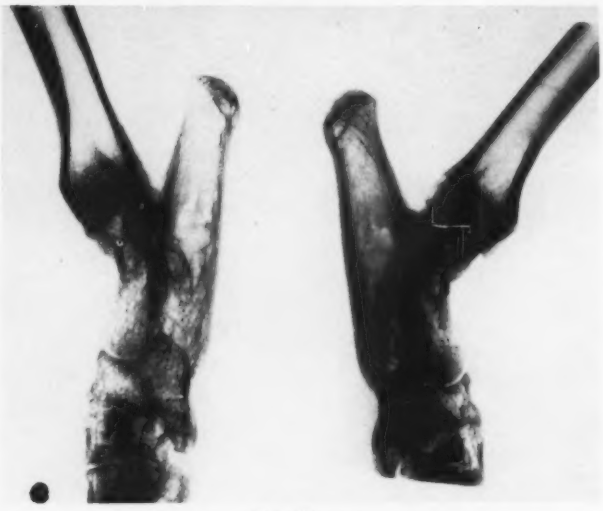

FIG. 33

Radiograph six weeks after a fracture and wire fixation of the tibia and plaster immobilisation with the foot plantarflexed. Marked osteoporosis of the foot and lower end of tibia on the affected side (*at left*).

Effect of fracture together with plaster immobilisation (fourteen rabbits)—In this series of experiments immobilisation and injury were combined by performing an osteotomy, thereafter stabilising the fragments by internal fixation with wire and immobilising the limbs in plaster. A long oblique osteotomy was performed in the lower half of the right tibia, the left serving as a control. After exact reposition the fragments were fixed by three or four stainless steel wires looped round the bone at the fracture site. We supplemented the internal fixation by the type of plaster case that we have described above with the foot in plantarflexion. The animals were killed 7, 8, 10, 12, 14, 17, 21, 28, 35, 42 and 49 days after the operation.

Results—We observed the same changes in the radiograph as after simple plaster immobilisation with the foot in plantarflexion. The bone rarefaction was slightly more severe than after tenotomy, but the angiographs showed the same marked increase in vascularisation during the period of bone rarefaction in both cases (Figs. 33 and 34).

Comment—The experiments did not give evidence of any osteoporosis that could be directly attributed to trauma apart from the bone resorption at the ischaemic ends of the bone fragments. The bone rarefaction in the foot did not differ from that observed after effective immobilisation in plaster (that is, with the ankle in plantarflexion).

FIG. 34
Angiographs twelve days after fracture and wire fixation of the tibia and plaster immobilisation. There is increased vascularisation on the side of the operation (*at left*).

EXPERIMENT 5

As it had been reported (Herfarth 1924) that the osteoporosis that follows the removal of the peritendinous tissue about the tendo calcaneus may be due to the division of the sympathetic nerves we investigated this point in the next experiment.

Resection of peritendinous tissue about the calcaneal tendon (two rabbits)—In two rabbits we excised the peritendinous tissue from the tendo calcaneus without cutting the tendon itself. The animals were left free after operation, and radiographs were taken at intervals during several weeks. The animals used the hind limb that had been operated upon as much as they used the control limb.

Results—After resection of a centimetre-long strip of peritendinous tissue no change could be observed in the bone structure of the leg. We could not repeat the results of other workers with this technique: possibly in their series other factors impaired the function of the calf muscles after the peritendinous resection.

Comment—Since the first two rabbits operated upon did not show any departure from the normal, this experiment was discontinued.

EXPERIMENT ON BONE RECONSTRUCTION

At this stage of our work we had collected data suggesting that the single common factor in the causation of bone resorption was the suppression of contraction of the calf muscles. We therefore next investigated the behaviour of the osteoporotic bone after the muscle activity had been restored.

Effect of mobilisation after removal of plaster (eight rabbits)—After immobilisation of a hind limb for three or four weeks in a plaster which extended from the toes to the knee the animals were left free and were radiographed, and finally injected and killed at different intervals.

Results—After free movement was allowed to the animal, a partial reconstruction of the rarefied bones in the foot occurred (Fig. 35). After the muscle started to transmit its constricting

force to the rarefied bone new bone was formed, as was clearly demonstrated in the radiographs and in the histological sections. But sometimes there was a disproportion between the compressing force and the capacity of the bone to withstand it. In such cases spontaneous

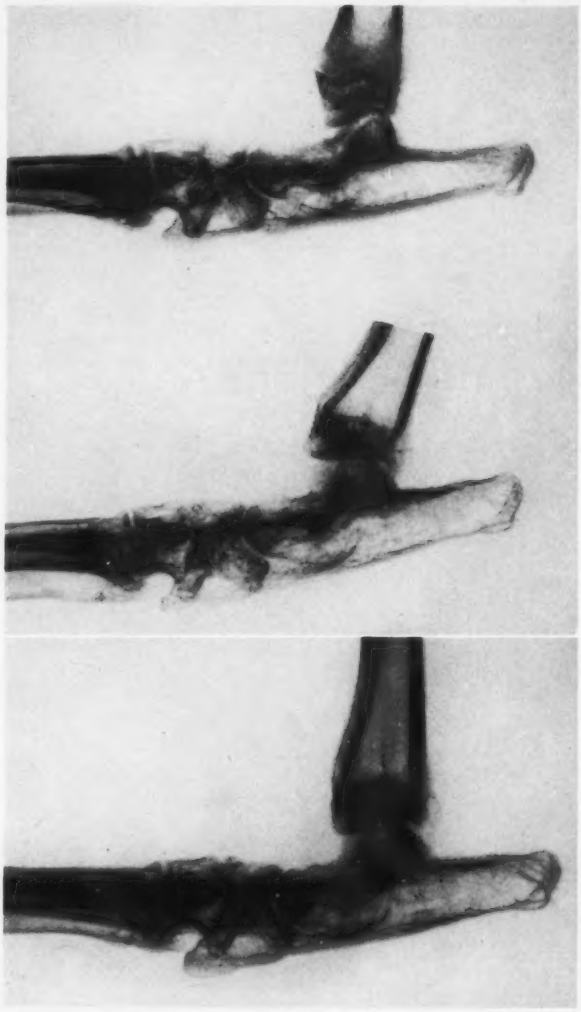

FIG. 35

Radiographs showing new formation of bone after resumption of activity. *Top*—Foot before immobilisation in plaster. *Middle*—Foot after four weeks' immobilisation in plaster in slight plantarflexion. *Bottom*—Four weeks after removal of the plaster. Note reconstruction of the fan of trabeculae and the lower and upper cortices.

fractures occurred (Fig. 36). This complication, which is well recognised clinically in cases of bone rarefaction from any cause, clearly demonstrates the weakening effect of immobilisation in suppressing the considerable force of muscle action. The reconstruction of bone seems to be a much slower process than its resorption. It takes some time before the previously

FIG. 36

Spontaneous fracture of the calcaneum in a rabbit which was left free after three weeks' plaster immobilisation. The sound side is shown for comparison.

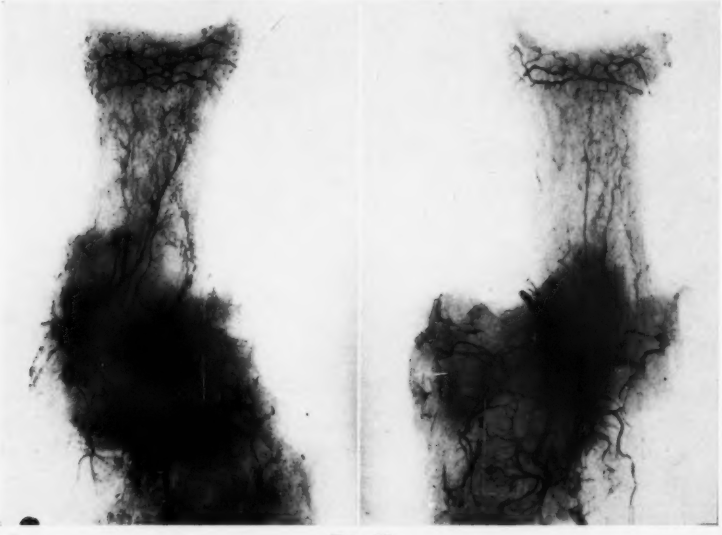

FIG. 37

Angiographs four weeks after resumption of activity after four weeks' plaster immobilisation. There is obvious hypervascularisation in the affected foot (*left in the picture*), when at that time bone reconstruction was taking place. See also Figure 35 which shows the normal radiographs of this rabbit.

immobilised animal uses its calf muscles properly. Thus the first radiographic signs of bone reorganisation did not appear until three or four weeks after the plaster had been removed, whereas bone rarefaction after tenotomy was already obvious at the end of the second week. But the histological investigations which were undertaken 2, 11, 16, 21 and 29 days after immobilisation was begun show that after eleven days the appearance of the bone had already changed. One had to examine the sections carefully to find a few osteoclasts, if any. Instead, we found everywhere rows of osteoblasts and layers of new bone in close relationship to the vessel walls (Fig. 38). Nevertheless, the hypervascularisation continued.

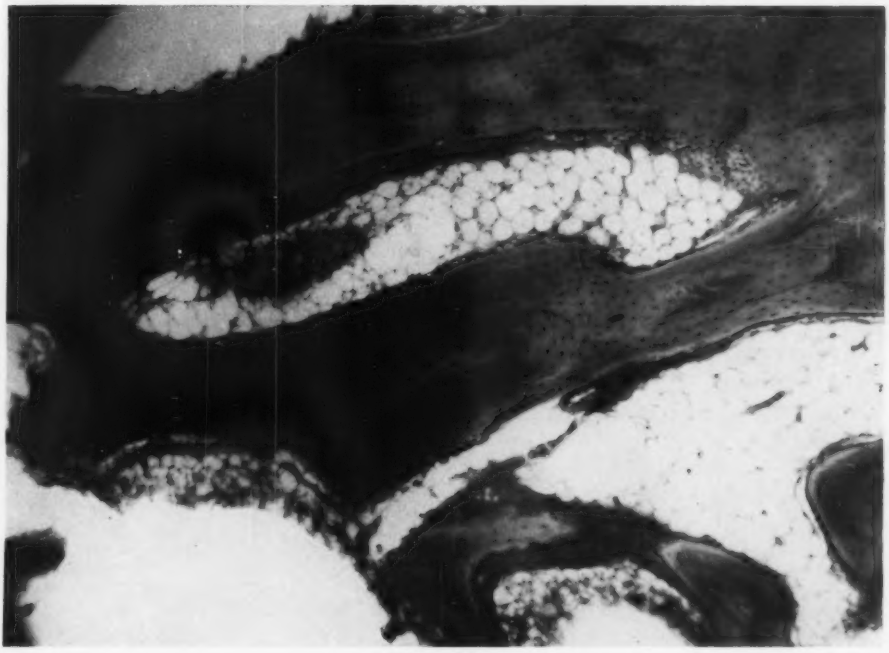

FIG. 38

Sagittal section through calcaneum sixteen days after three weeks' immobilisation in plaster-of-Paris. Note the close relationship between vessels and new bone.

DISCUSSION

For some years one of the main subjects of study in this centre has been the remodelling of bone structure caused by the transmission of strains and stresses through bone, particularly those of gravity, and a number of papers have been published or are in the process of publication (Harrison, Schajowicz and Trueta 1953; Trueta 1953, 1954, 1956*a*; Stringa 1957). Except for the preliminary note on the work here reported (Trueta 1956*b*) this is the first detailed study we have made of the changes caused in bone by the suppression of muscular force.

In the rabbit, tenotomy of the calcaneal tendon, immobilisation of a hind limb by means of plaster-of-Paris, and osteotomy of the tibia fixed with wire circlage and a plaster, are followed by bone rarefaction in the foot and tibia, detectable both in the radiographs and in histological sections. Excision of the peritendinous tissue around the calcaneal tendon in two animals caused no changes in the bone. Isometric muscle contractions by means of a faradic stimulation of the calf muscles in a leg immobilised in plaster tended to reduce bone rarefaction.

The process of bone removal was progressive and reached its final state at the sixth week after the beginning of the experiment. When the plaster-of-Paris was removed after three or four weeks the rarefying process was interrupted and reconstitution of bony structure occurred (Fig. 35). Similar results were obtained by tenotomy and osteotomy circlage of the tibia, both in the micro-angiographs and in the microscopic sections. They demonstrated clearly a considerable increase in vascularity and osteoclastic activity from the fourth week onwards. At the end of the sixth week, obviously because of the large amount of bone removed by then, we observed a reduction of the vascular bed, which seemed related to the amount of bone left behind. While a certain limited hypervascularity occurred during the first few days it was beyond any doubt that the destruction of bone was connected with a very impressive increase in vascularity. Our findings confirm the relation established long ago between bone rarefaction as seen in radiographs and " hyperaemia." It is widely believed that circulatory stasis, oedema and acidosis following " hyperaemia " are the real factors responsible for the removal of bone and this conception agrees with all our data (Beck 1925, Dubois 1932, Rieder 1936).

We have seen in this paper that bone formation is also connected with increased vascularity (Fig. 37), a fact well known in the ossification zone of growing bone. We have also shown that after bone rarefaction has taken place a marked reduction in the number and size of the vessels occurs, according to the amount of bone left behind. Thus bone destruction as well as bone formation are connected with an increased vascular bed, and consequently it does not seem logical to regard hyperaemia (or better, increased vascularity) as responsible for the removal of bone. There is obviously a great difference between the hypervascularity during bone removal and that during bone formation. The explanation for this may be that bone formation is usually a slower process than bone removal, as we have already mentioned. A possible mechanism by which this increased vascularity contributes to the laying down of lamellar bone was suggested in a previous paper by one of us (Trueta 1956*a*) and will be the subject of a more detailed analysis elsewhere (Fig. 38).

All our experiments, except those using a simple plaster-of-Paris case to immobilise the feet, were followed by some hyperaemia due to the healing of the operation wound. But simple excision of the peritendinous tissue round the calcaneal tendon, which was also followed by hyperaemia, did not cause any bone rarefaction; and with faradic stimulation under plaster, which induced a considerable hyperaemia producing even a haemorrhagic effusion in the ankle joints, there was only a limited bone rarefaction. There must be, therefore, another factor balancing bone rarefaction and bone formation, which uses a raised vascular activity to reach its aim. We could thus not confirm the views of Leriche (1930, 1939) and Fontaine *et al.* (1953, 1956) on the cause of post-traumatic decalcification.

All our experiments that caused bone rarefaction had one thing in common; they inhibited function of the calf muscles or made their function extremely inadequate. In analysing the forces transmitted to the skeleton of the foot and to the tibia during a rabbit's jump we obtain a picture like that in Figure 39. With the lines shown in that picture we do not intend to support the trajectorial theory (Meyer 1867, Wolff 1870, Koch 1917). They simply show that although the calf muscles at first sight seem to be pulling, nevertheless pressure forces almost alone are transmitted through the bones of the foot and leg. A similar drawing could be made for the foot in man even though he does not progress by jumping. Thus it is convenient to bear in mind that bone is stressed by muscle action as well as by the pressure of gravity (Wyse and Pattee 1954).

In all our experiments that succeeded in inducing bone rarefaction the only common factor was the interruption of transmission of muscle force to the foot and leg. Consequently, the mechanical pressure forces produced by muscle action to counteract gravity seem to be a most important factor for the maintenance of bone structure. It may be suspected that lack of muscle action accompanying Sudeck's syndrome plays an important part in causing the

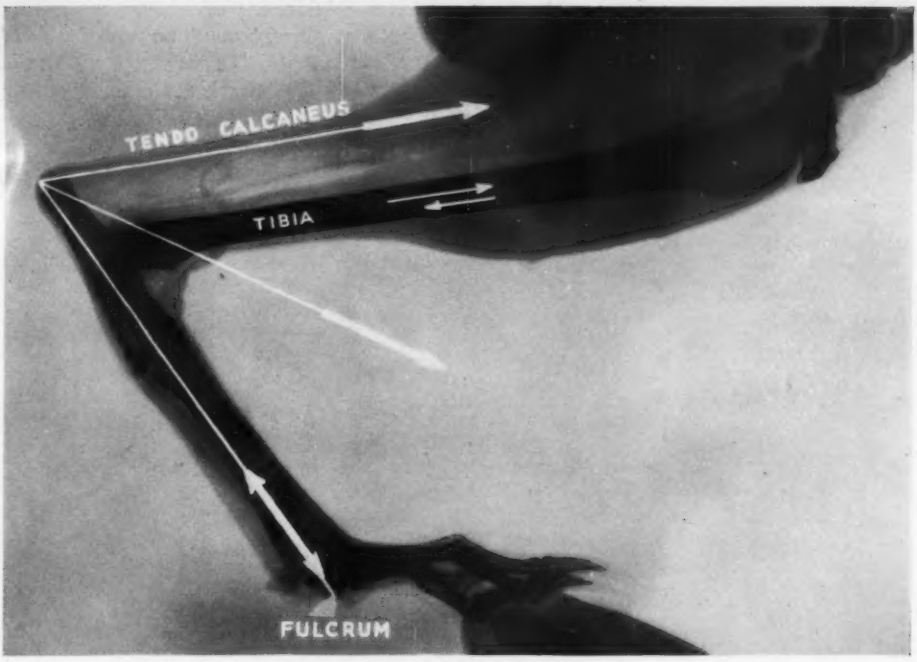

FIG. 39

A rabbit's leg during a jumping movement shortly before the foot is leaving the ground. The white arrows should give an idea of the forces arising in the bones during this movement.

extreme bone rarefaction characteristic of that condition; It is even to be wondered whether in the inhibition of muscle contraction we do not have the greatest single responsible factor in establishing Sudeck's atrophy. How the lack of muscle contraction reduces lymphatic flow and causes retention of tissue fluid was investigated some years ago by Barnes and Trueta (1941). The much greater frequency with which Sudeck's syndrome occurs on the European continent than in Britain may perhaps be explained by the insufficient emphasis on the importance of energetic muscle exercise after injuries of the hands and feet which is found in some Continental centres.

SUMMARY

1. In five series of experiments in eighty-two rabbits we succeeded in causing rarefaction of the calcaneum of all the animals soon after it was relieved from muscular compressing forces; new bone was generated when the calcaneum was subjected again to the stresses and strains of muscle contraction.

2. We found evidence that during muscle action pressure forces are transmitted through the bone, and that the presence or absence of these pressure forces conditions the balance between bone formation and bone removal.

3. In the calcaneum of the rabbit lack of muscular action seems to be the most important factor inducing osteoporosis. It is possible that the origin of post-traumatic osteoporosis has the same basis.

4. In our experiments bone rarefaction was characterised by a great increase in the vascularity of the bone; this increase ceased when the bone reached its final precarious bone density. Thus, vascular over-activity accompanied the removal of bone; but bone reconstruction was also seen to be accompanied by a more localised increase in vascularity.

5. From our experiments we cannot suggest that the inhibition of muscle contraction accompanying Sudeck's syndrome is responsible for this disorder, because we were unable in our animals to cause any of the other signs characteristic of Sudeck's bone atrophy. But the constancy with which we caused bone atrophy by the removal of muscle action may possibly help to explain the mechanism of bone absorption accompanying Sudeck's disease.

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ROTATION MOVEMENTS OF THE SPINE WITH SPECIAL REFERENCE TO SCOLIOSIS

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In the latter half of the nineteenth and early part of the twentieth centuries surgeons and anatomists studied the movements of the spinal column, both in the living and in the cadaver (Weber and Weber 1836, Schulthess 1899, Lovett 1905, Virchow 1907, Fick 1910, Strasser 1913). These researches culminated in the work of Lovett (1905), who concluded that the spine is a tube of unequal flexibilities, that rotation and lateral bending are inevitably linked, that rotation does not occur in the lumbar region, and that side-bending does not occur in the thoracic region. Lovett stated: " in forward flexion, lateral flexion is associated with rotation to the convex side. In extension, lateral flexion is associated with rotation to the concave side." He did not state what happens in the neutral position. Lovett also implied that scoliosis is an exaggeration of a normal movement and that the mechanism of its production can be deduced from a study of models exaggerating one or other feature of unequal flexibilities.

Frazer (1940) assumed that the axis of rotation is in the centre of the vertebral body. From this assumption he concluded that the shape of the articular facets prevents rotation in the lumbar region or side-bending in the thoracic region.

It will be clear that observation of the movements of the vertebral bodies in the adult model is necessarily indirect. In the formalin-hardened cadaver the intervertebral disc loses its normal plasticity, and the post-mortem specimen does not necessarily reproduce exactly the movements of the living spine. Furthermore, the older investigators were influenced by *a priori* considerations and had not accepted the concept of an inconstant axis of movement in joints.

With the development of radiology, spinal movements have been reinvestigated and, first, flexion, extension, and, more recently, side-bending movements have been studied (Bakke 1931, Brailsford 1934, Steindler 1929, Tanz 1950, Begg and Falconer 1949, Wiles 1935). There has, however, been comparatively little recent work on rotation movements, either in the living subject or in fresh, flexible, necropsy specimens. It seemed, therefore, worth re-examining 1) the normal movements of the spine, noting in particular whether the spine does, in fact, behave as a tube of unequal flexibilities and whether side-bending and rotation are inevitably linked; and 2) the relationship between movements of the normal spine and the deformity of scoliosis.

MATERIAL FOR STUDY

For the purpose of this investigation there were two sources of material: 1) spines of stillborn babies, first preserved by freezing and then dissected free of all muscles after thawing; and 2) radiological examination of the spines of normal children. The results of these investigations are represented in Figures 1 to 9 and may be summarised as follows.

The young spine is a tube of roughly equal flexibilities; the axis of rotation is in the region of the posterior longitudinal ligament; lateral flexion and rotation normally occur independently and in both the thoracic and lumbar regions. It is true that, in the cervical region rotation is associated with a slight screwing-up on the side away from the direction of rotation and screwing-down on the opposite side. Finally, severe scoliosis is not just an exaggeration of a normal movement: it is fundamentally an abnormal rotation—often three to four times the normal range and deserves to be called a luxation, as the ancients called it.

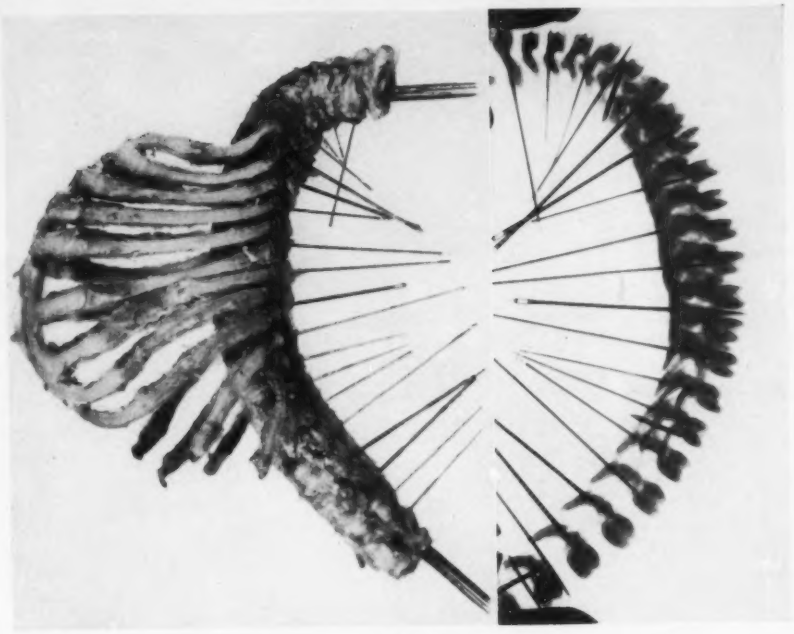

FIG. 1
Extension of normal infant's spine.

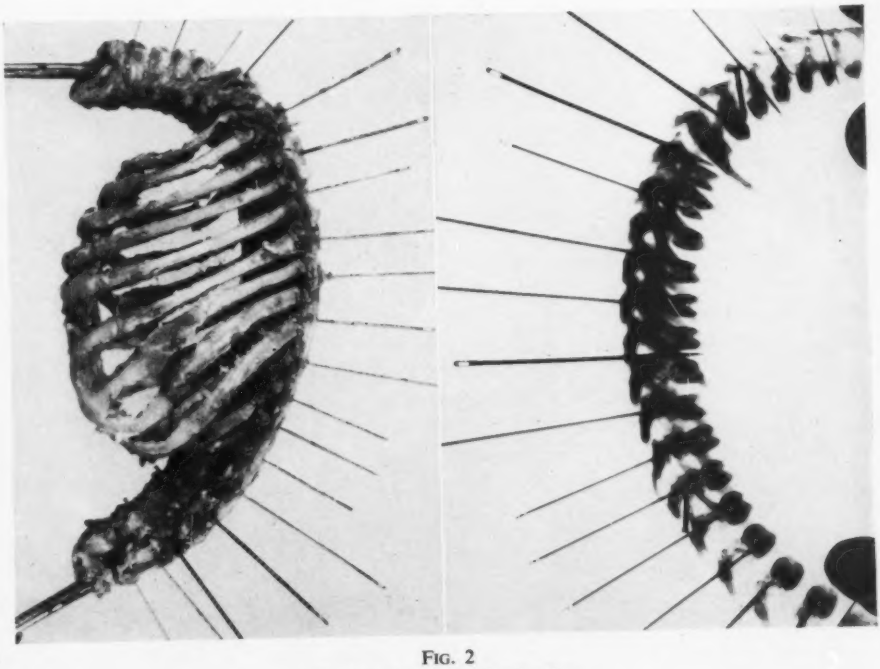

FIG. 2
Flexion of normal infant's spine.

It will be realised 1) that there is a certain degree of individual variation; 2) that the axis about which rotation occurs may shift just as the axis of flexion-extension does; and 3) that the degree and nature of intervertebral movement is affected by the turgidity of the nucleus pulposus—for instance, decompressing the nucleus pulposus by making a tiny incision in the annular fibres and extracting the nucleus pulposus causes a big increase in lateral sliding and rotation between the vertebral bodies.

This is not the place to discuss the bearing these observations have on referred spinal pain, except to say that such pain is usually due to disorders of rotation and that this is the key to rational treatment.

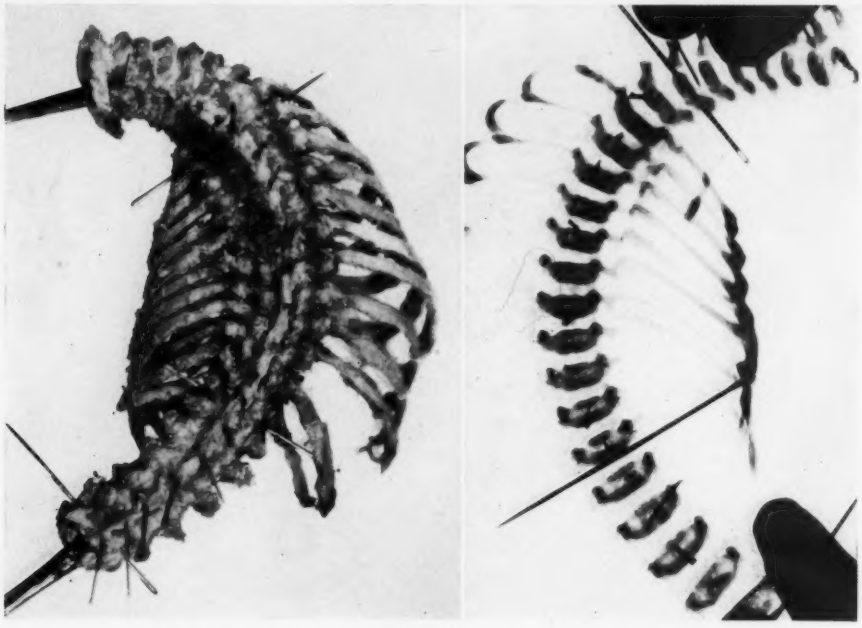

FIG. 3
Side-bending of normal infant's spine. Note absence of rotation.

To return to scoliosis, even if the spine is artificially converted into a tube of unequal flexibilities, it cannot be made to assume the usual deformity of scoliosis (Somerville 1952) (Figs. 10 to 15). In order to reproduce a scoliotic deformity one must divide most of the spinal ligaments and then realign the vertebrae in positions of forced rotation (Figs. 16 to 19).

It is worth noting that if, say, the direction of rotation is clockwise in the upper part of the curve, it must be anti-clockwise in the lower part (Fig. 20).

There are two types of scoliosis, which occur independently of etiology. The first is an uncommon type in which lateral flexion is the dominant element. The curve usually remains relatively mobile, is fairly easily corrected, has less tendency to relapse after fusion, and presents minimal rib deformity; basically it is an exaggeration of a normal movement (Fig. 21).

The other type of curve, in which rotation is the main feature, tends to be progressive; it soon becomes rigid and resistant to correction, and tends to relapse after fusion for two reasons. Firstly, there is an internal torsion and asymmetry of the vertebrae themselves which

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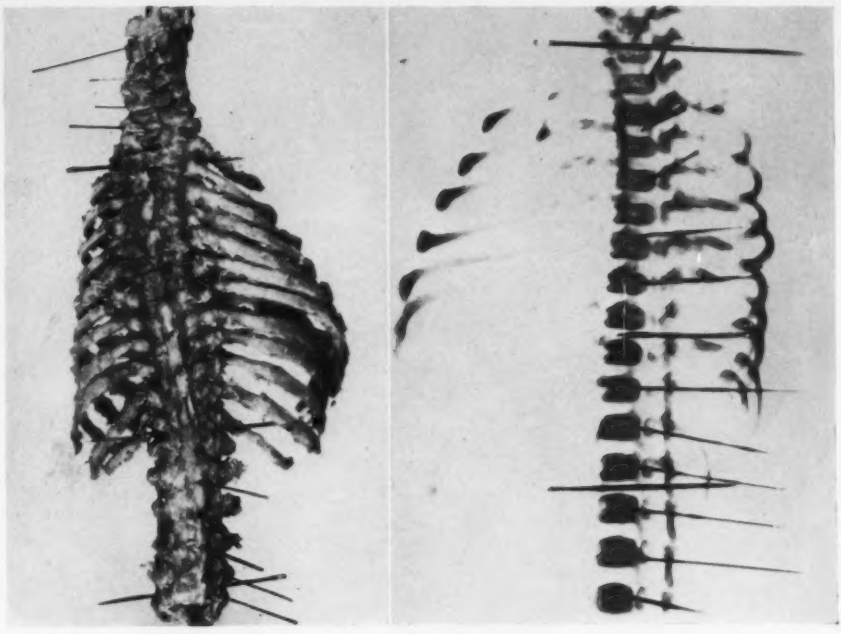


FIG. 4
Rotation. Note absence of side-bending.

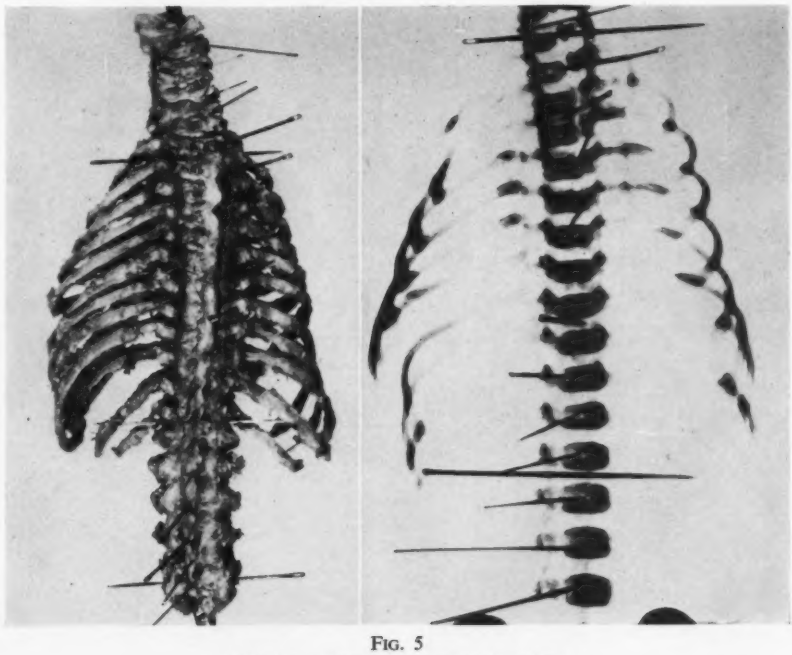


FIG. 5
Rotation. Note absence of side-bending.

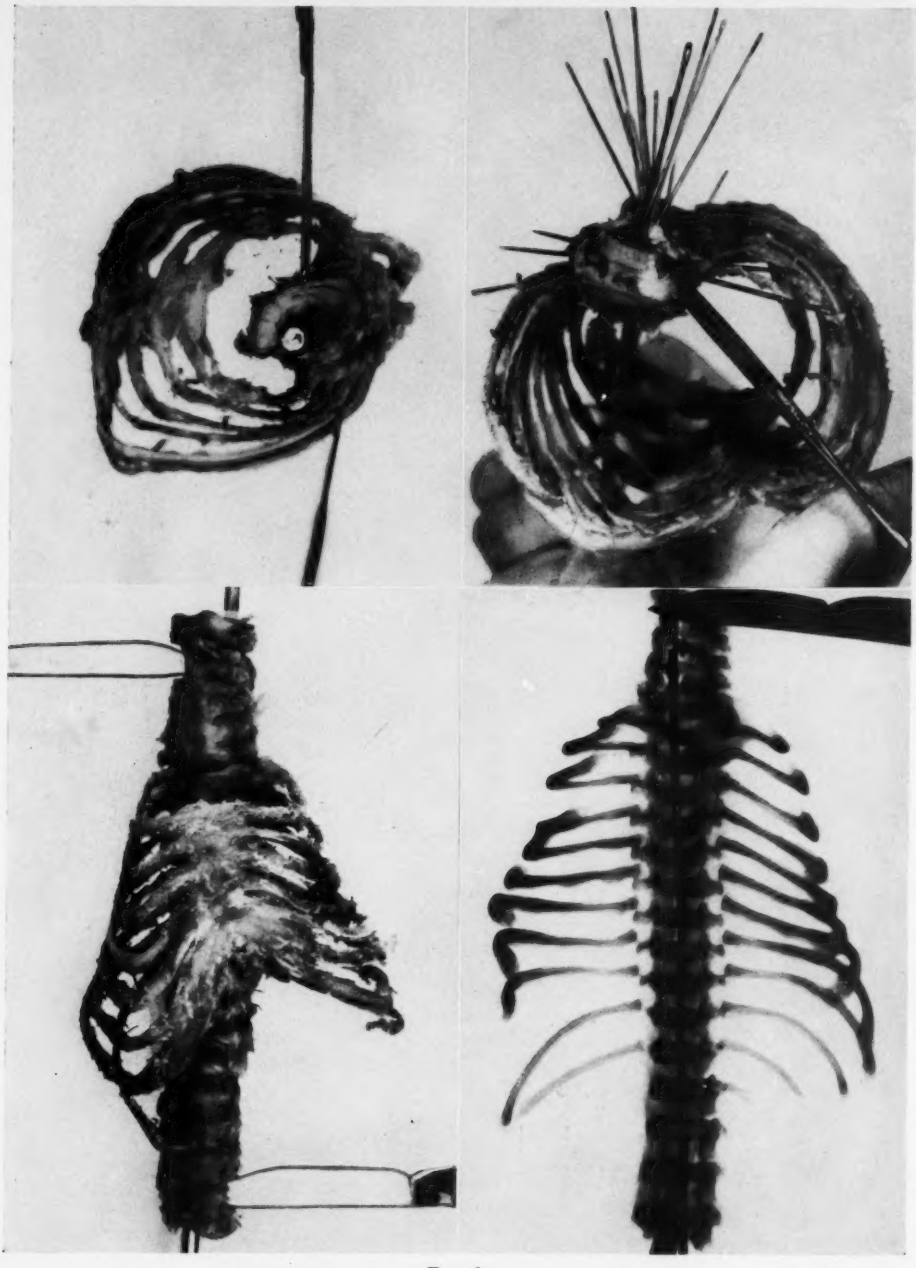


FIG. 6

Rotation. The axis of rotation is in the region of the posterior longitudinal ligament. Note that all movements are roughly equal and evenly distributed throughout the spine.

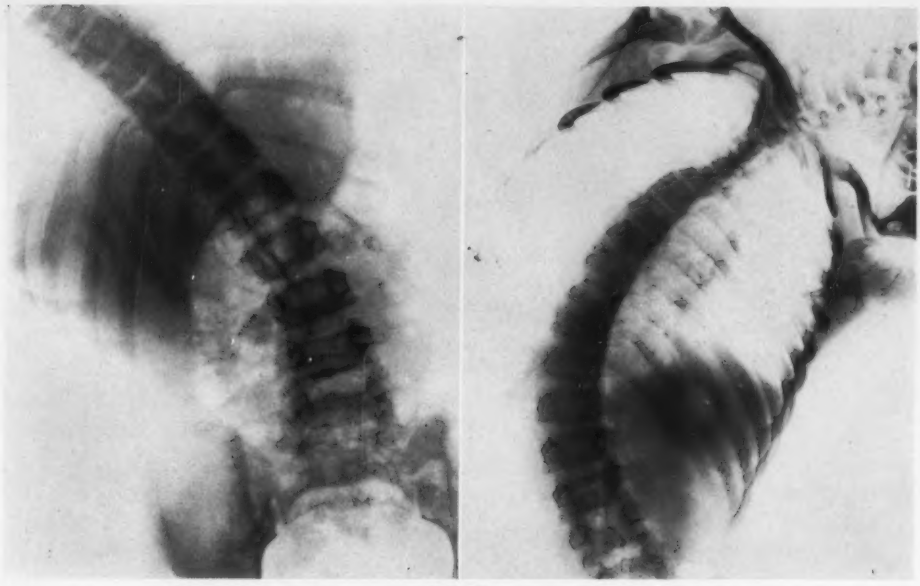


FIG. 7
Spine of eight-year-old boy, in lateral flexion. Note absence of rotation.

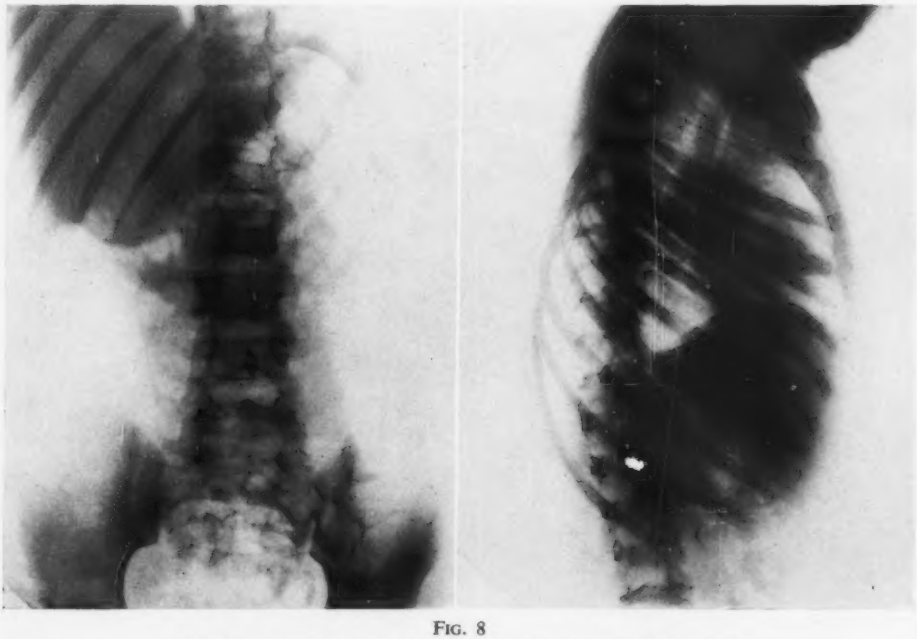


FIG. 8
Spine of eight-year-old boy, in rotation. Note absence of side-bending.

FIG. 9

Spine of eight-year-old boy. If an effort is made to combine rotation and side-bending, the result is rotation and forward flexion.

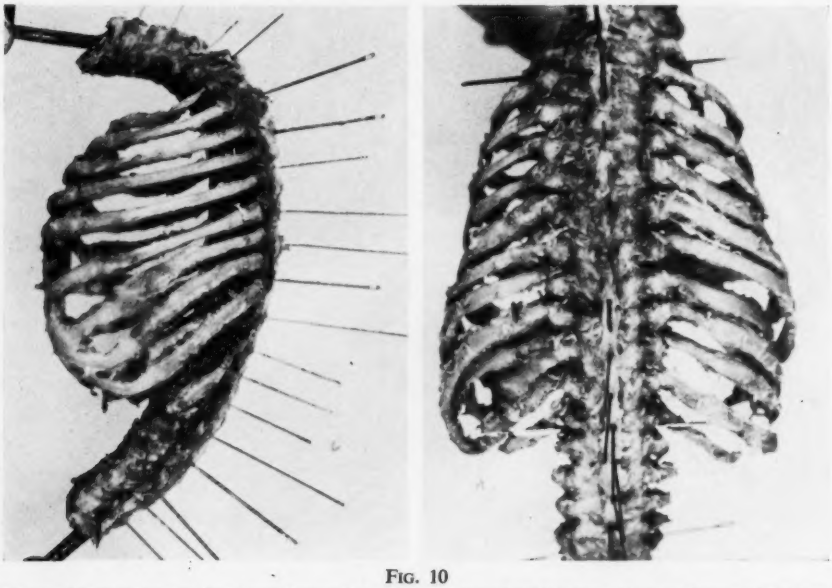


FIG. 10

Three spinous processes have been fastened together. In forced flexion there is no tendency to rotation.

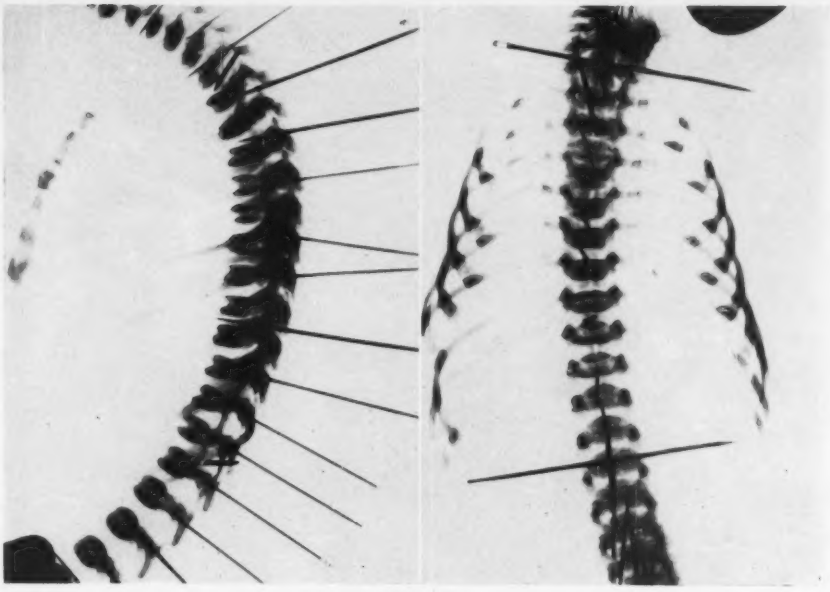


FIG. 11
Same spine as in Figure 10, radiographed in forced flexion. No tendency to rotation.

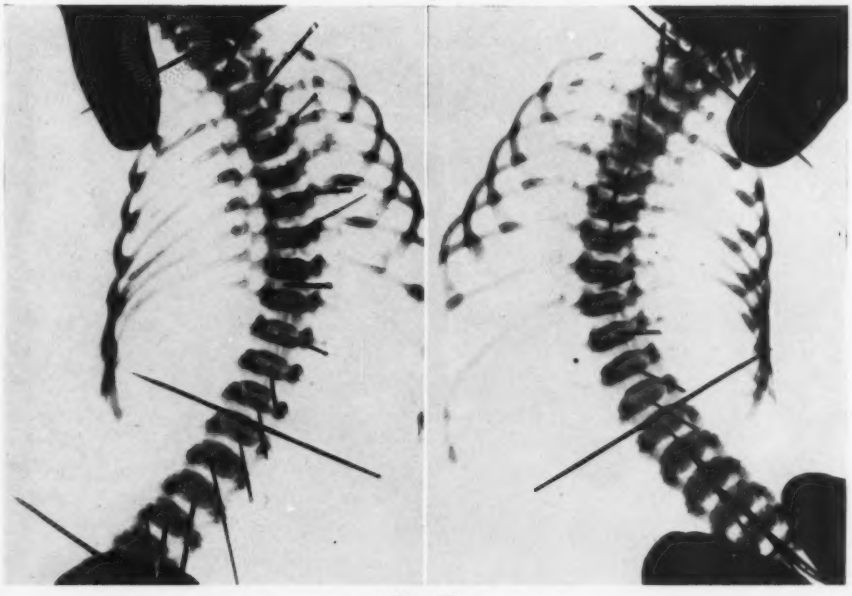


FIG. 12
Same spine as in Figures 10 and 11, radiographed in forced lateral flexion. No tendency to rotation.

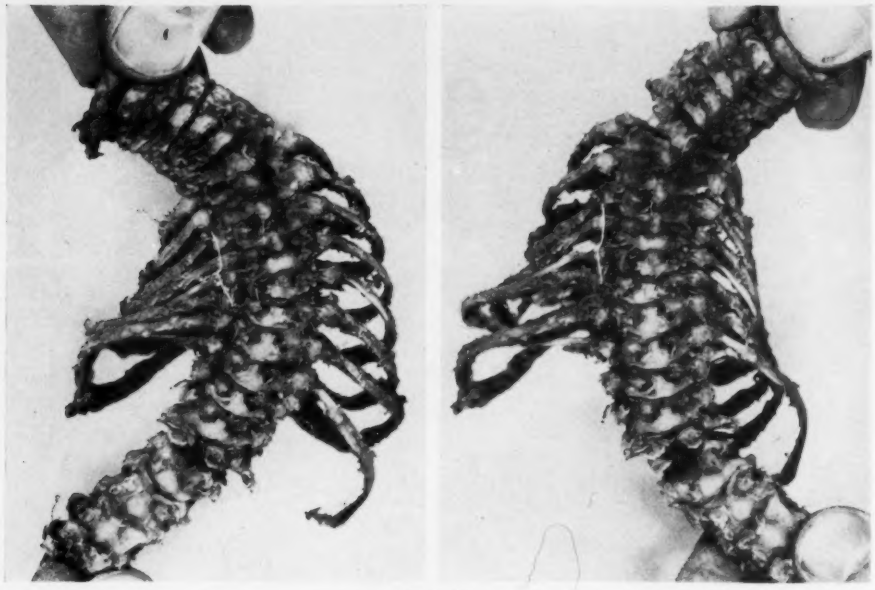


FIG. 13
Three transverse processes have been fastened together. In side-bending to the left or right there is no tendency to rotation.

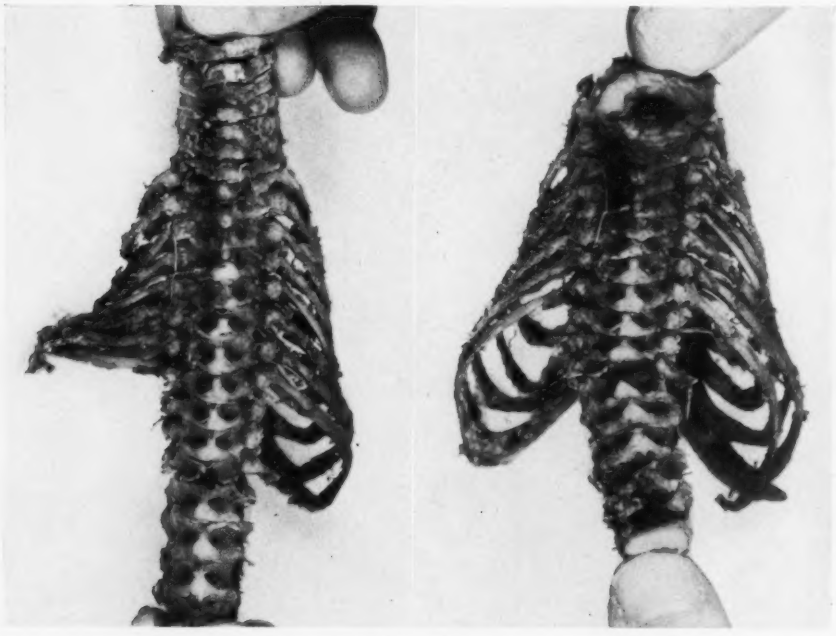


FIG. 14
Same spine as in Figure 13. In extension or flexion there is no tendency to rotation or lateral flexion.

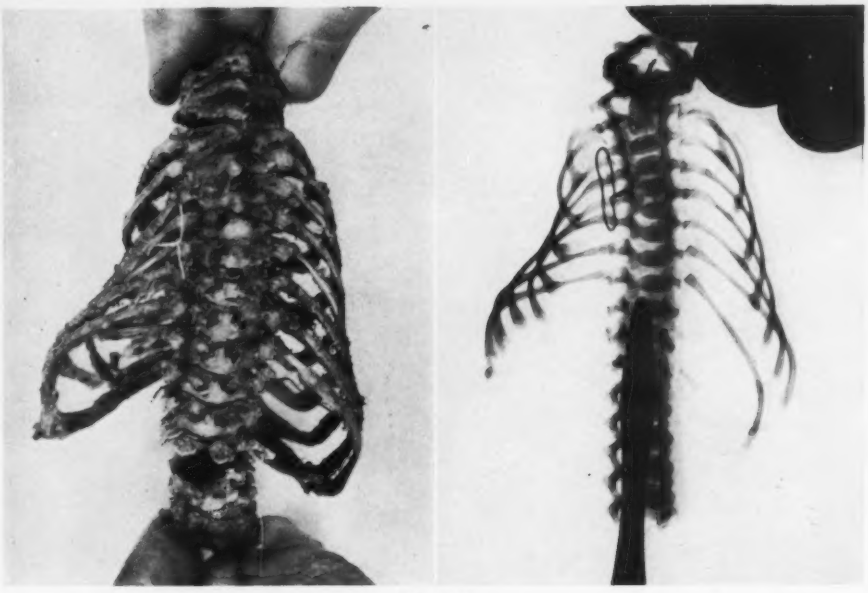


FIG. 15

Same spine as in Figures 13 and 14 specimen and radiograph with the spine flexed.

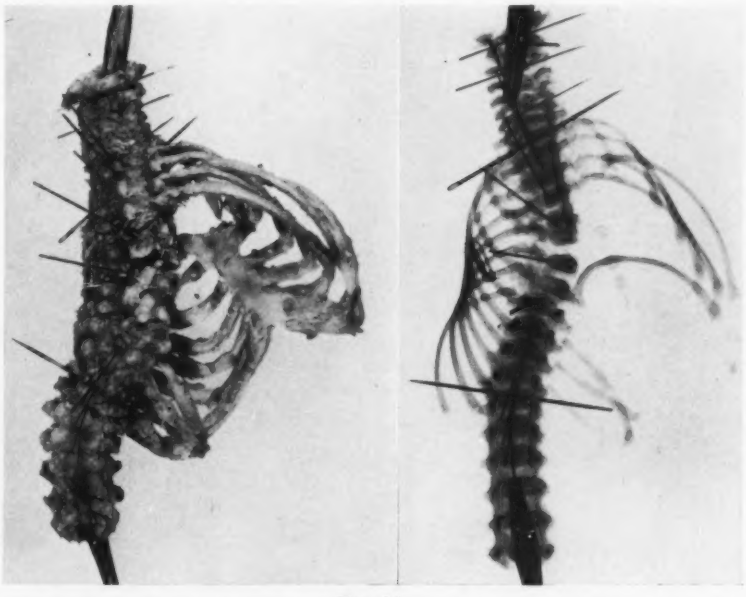


FIG. 16

In order to reproduce a deformity resembling scoliosis, even in a neonatal spine, many ligaments must be divided and a rotational subluxation produced.

FIG. 17

FIG. 18

Figure 17—Reconstruction of scoliotic spine by fastening vertebrae together in forced rotation but no lateral flexion. Figure 18—Radiograph of the artificial scoliosis. Shadows of plasticine mark areas where oblique fibres of erector spinae muscles have a mechanical advantage.

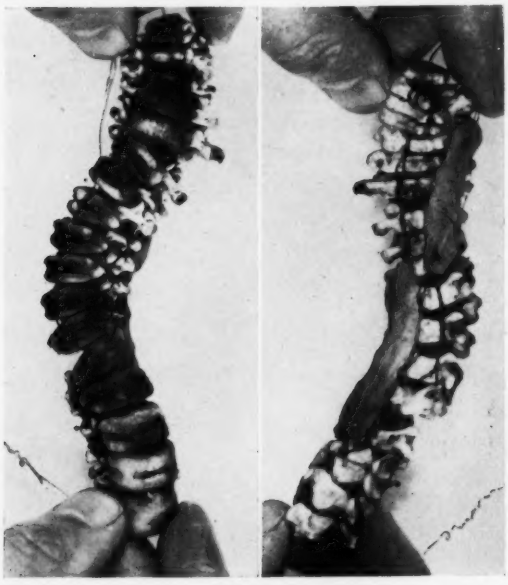


FIG. 19

Reconstruction of scoliotic spine by fastening vertebrae together in forced rotation but no lateral flexion. Plasticine marks areas where oblique fibres of erector spinae muscles have a mechanical advantage.

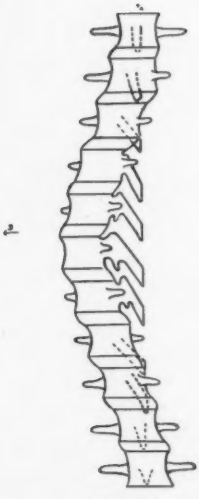


FIG. 20

Drawing to show that rotation in one direction in the upper part of the curve must be balanced by an equal rotation in the opposite direction in the lower part of the curve.

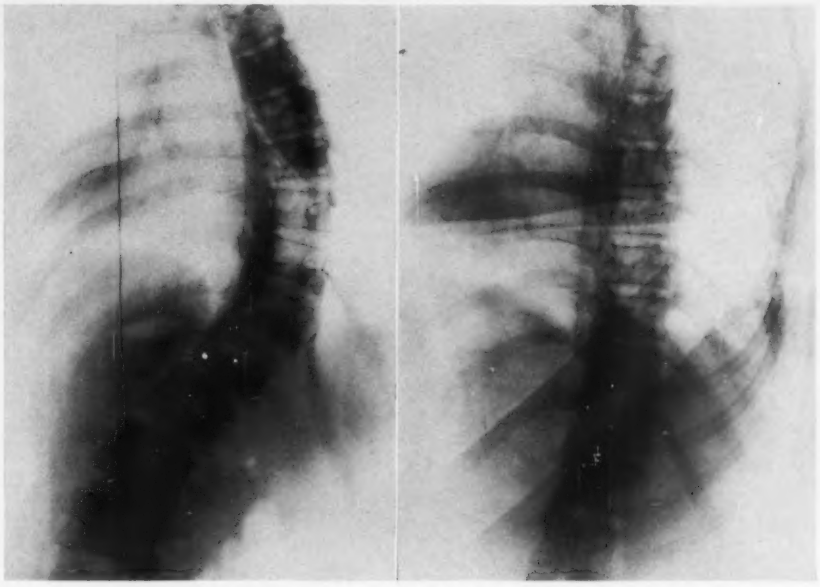


FIG 21
Lateral flexion type of scoliosis (with minimal rotation) before and after correction, which is easily obtained in this type.

is largely confined to the neural arch. At the centre of the curve the laminae and pedicles on the convex side are larger so that there is a bigger difference in both sagittal and longitudinal planes between the superior and inferior articular facets than on the concave side. At the ends of the curve the asymmetry is reversed (Figs. 22 to 28). Secondly, in consequence of the rotation, six secondary deforming factors come into action which inevitably tend to increase the deformity. (The deformity, incidentally, is often wrongly interpreted as a lateral flexion when it is really a lordosis (Figs. 29 and 30); in fact, but for the lordosis, the spine could never return to the mid-line and would be permanently out of balance.) *Firstly*, the normal action of the longitudinal fibres of the erector spinae muscle is to advance the vertebrae at the centre of their span. This forward movement is normally opposed by gravity. If the vertebrae are rotated their movement is unopposed, so that every muscular contraction pushes them farther from the mid-line and increases the lordosis (Fig. 31). *Secondly*, gravity acts asymmetrically, causes a secondary lateral flexion and also possibly checks growth on the concave side (Figs. 32 and 33). *Thirdly*, the deep transverse fibres of the erector spinae muscles in the upper part of the convexity and lower part of the concavity act more directly than their obliquely placed opponents and therefore have a mechanical advantage (Fig. 34). *Fourthly*, the distorted rib cage is both an obstacle to correction and itself creates a couple of forces which tends to increase rotation (Fig. 35). *Fifthly*, since the upper and lower surfaces of the vertebral body are not usually parallel, the effect of rotation is to direct the lower vertebral surface sideways (Figs. 36 and 37). *Lastly*, if fusion is performed before growth is complete the graft may act as a tether at the back. In this case continued growth of the vertebral bodies causes increased lordosis and, in the presence of rotation, increased deviation from the mid-line (Figs. 38 to 41). Occasionally one meets patients with scoliosis in whom " reverse rotation " occurs—that is, the rotation is increased on straightening the curve and decreased on increasing the curve (Figs. 42 and 43). Such patients are another illustration that there is no inevitable link between rotation and lateral flexion.

FIG. 22

FIG. 23

FIG. 24

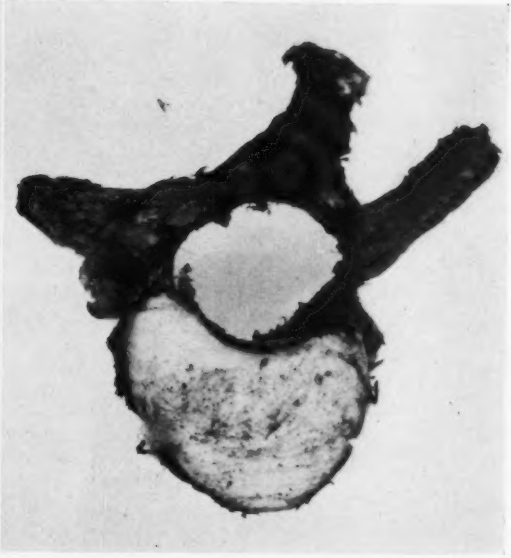


FIG. 25

Views of scoliotic vertebra. Figure 22—Posterior view. Note hypertrophy of lamina on convex side. Figure 23—Lateral view showing hypertrophy of pedicle on convex side. Figure 24—Lateral view of concave side. Figure 25—Axial view. Note hypertrophy of lamina and pedicle on convex side. Asymmetry of neural arch much more marked than of body. Bulk of erector spinae muscle is greater on convexity.

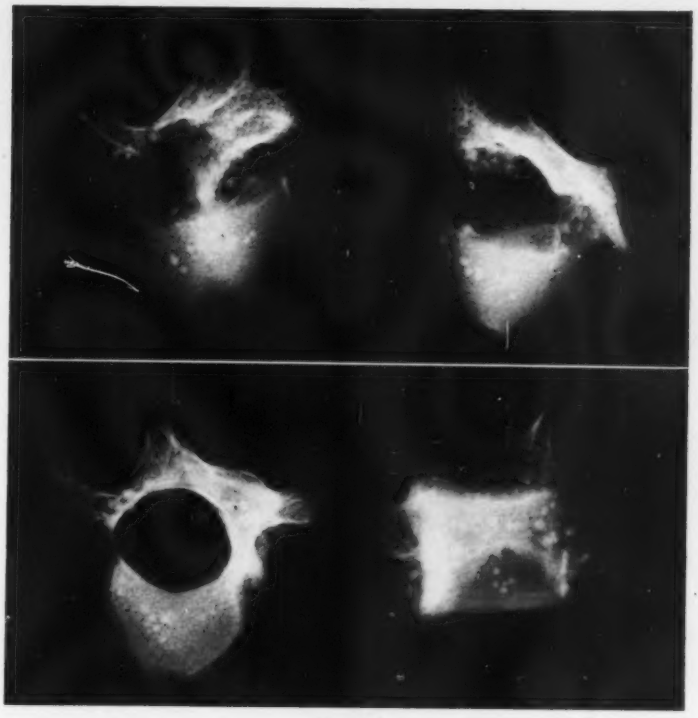


FIG. 26
Radiographs illustrating the features shown in Figures 21 to 24.

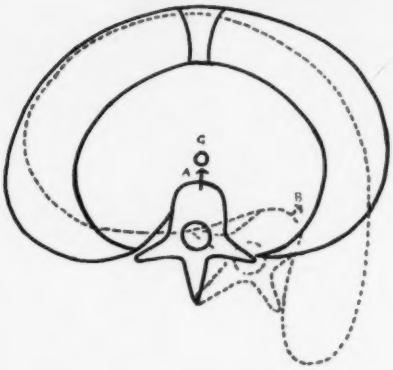
FIG. 27
Transverse section through spine at apex of scoliosis. Note lateral broadening of neural canal and spinal cord pressed against pedicles on concave side.

FIG. 28
Drawings of vertebral body. Dots mark articular facets. There is a greater distance in both longitudinal and sagittal planes between the facets on the convex side.

FIG. 29

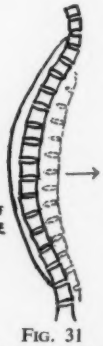
FIG. 30

Figure 29—Antero-posterior radiograph of 75 degrees of rotation of the vertebral bodies at the apex of the scoliosis. The vertebrae are seen in profile and apparent lateral flexion is really a lordosis. Figure 30—A similar example.



SHEWS : On extension rotated vertebra moves sideways when the spine is extended.
This movement is unopposed by gravity and tends to progress till the vertebra approaches the rib cage.

EFFECTS OF ROTATION (I)



On extending spine, vertebrae at the centre of the extending section move forwards relative to those at the ends.

FIG. 31

Indicates that contraction of the longitudinal fibres of the erector spinae tend to make scoliotic vertebrae, which are already pointing laterally, move farther laterally unopposed by gravity. This forward movement of a normal vertebra is opposed by gravity.

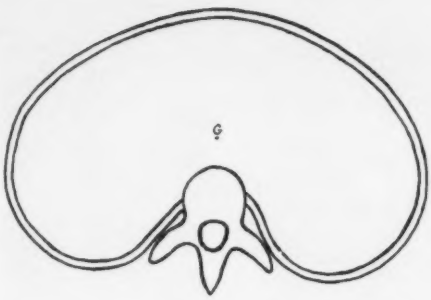


FIG. 32

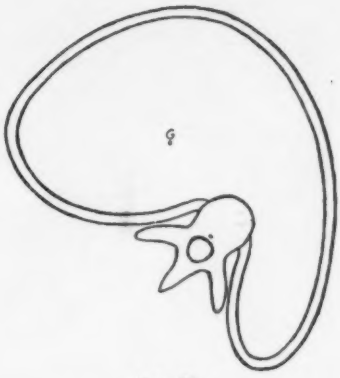
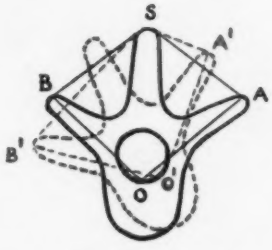


FIG. 33

Figure 32—Transverse section of normal thorax. Figure 33—Transverse section of scoliotic thorax. Note: 1) line of centre of gravity (G) falls to one side of vertebral column causing secondary lateral flexion and unequal pressure on growing epiphyses; 2) vertebral body points sideways.



EFFECTS OF ROTATION (II)

In neutral position AB the rotary action of the deep oblique fibres of the erector spinae is balanced $\angle SAO = \angle SBO$

In the rotated position A'B' $\angle SA'O > \angle SB'O'$, therefore, other things being equal, the muscles on the convex side act at an advantage

FIG. 34

Indicates that the oblique fibres of the erector spinae, which run from a spinous process to a transverse process of a lower vertebra, have a mechanical advantage on the convex side in the upper part of the curve and on the concave side in the lower part of the curve. These areas are indicated by plasticine shadows in Figures 18 and 19.

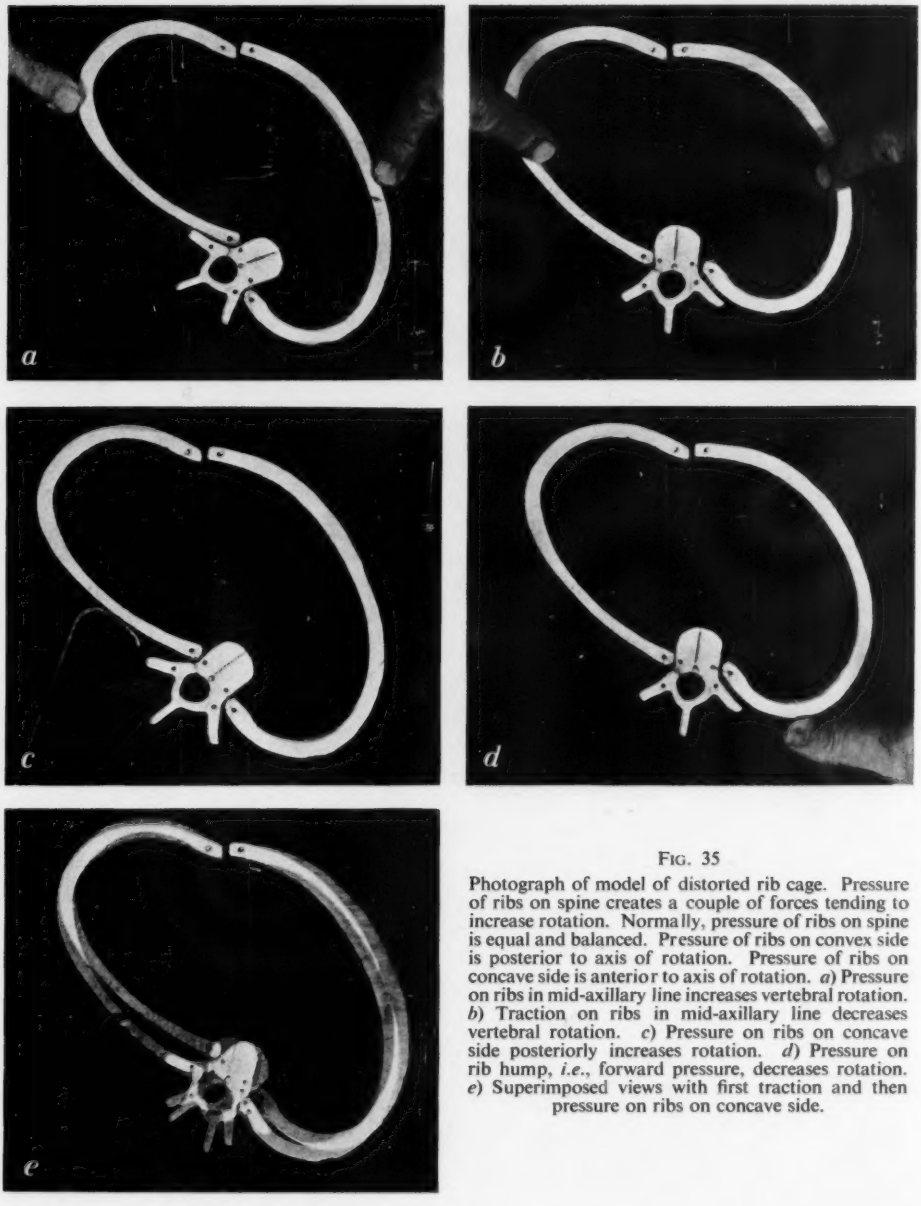


FIG. 35

Photograph of model of distorted rib cage. Pressure of ribs on spine creates a couple of forces tending to increase rotation. Normally, pressure of ribs on spine is equal and balanced. Pressure of ribs on convex side is posterior to axis of rotation. Pressure of ribs on concave side is anterior to axis of rotation. *a*) Pressure on ribs in mid-axillary line increases vertebral rotation. *b*) Traction on ribs in mid-axillary line decreases vertebral rotation. *c*) Pressure on ribs on concave side posteriorly increases rotation. *d*) Pressure on rib hump, *i.e.*, forward pressure, decreases rotation. *e*) Superimposed views with first traction and then pressure on ribs on concave side.

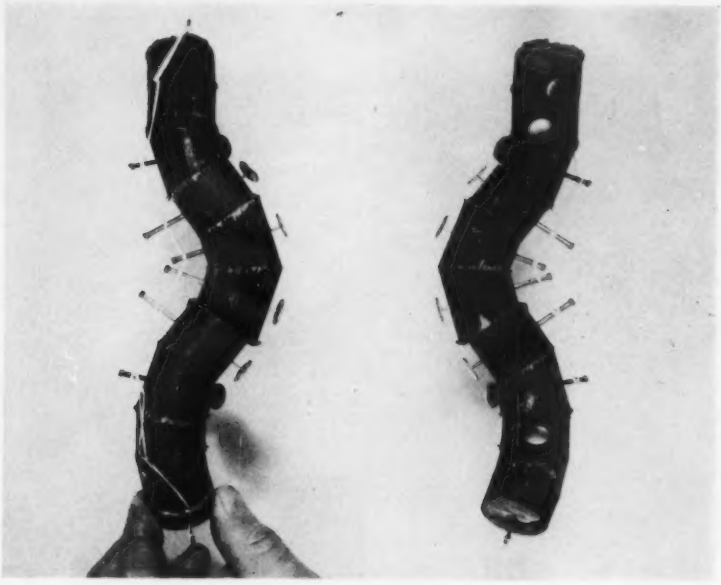


FIG. 36

Anterior and posterior aspects of a model of a scoliotic spine. Upper and lower vertebral surfaces are not parallel; therefore rotation alone will produce lateral deviation without any element of lateral flexion. Note in model lordosis at apex of curve (but for this, spine would not come back to the mid-line). Series of nails and string represents spinous processes. Line of drawing pins represents anterior longitudinal ligament.

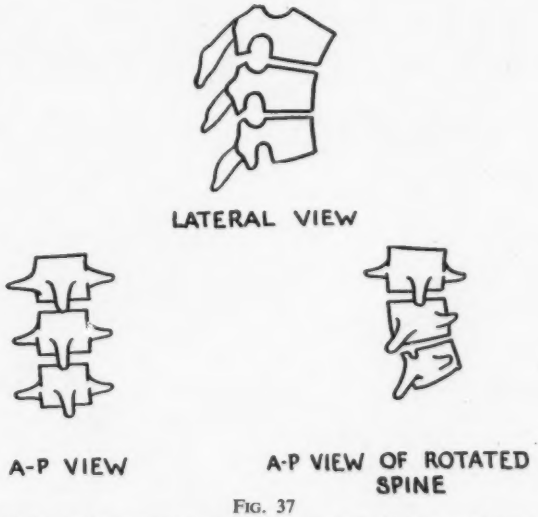


FIG. 37

Illustrates how rotation produces lateral inclination and lateral deviation without any lateral flexion in the presence of slight vertebral wedging.

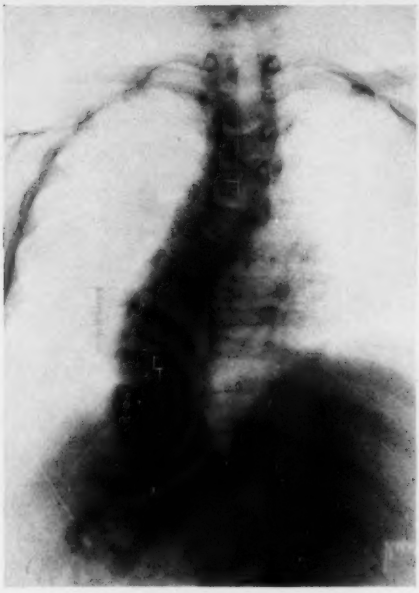


FIG. 38

FIG. 39

Figure 38—Antero-posterior radiograph of spine before laminal fusion. Note rotation of vertebral bodies.
Figure 39—Four years later. Continued growth of the vertebral bodies has caused increased lordosis due to the tethering action of the laminal fusion. This gives a false appearance of increased lateral flexion in the antero-posterior radiographs.

FIG. 40

FIG. 41

Figure 40—Antero-posterior radiograph of spine before laminal fusion. Note rotation of vertebral bodies.
Figure 41—Six years later. Continued growth of the vertebral bodies has caused increased lordosis due to the tethering action of the laminal fusion. This gives a false appearance of increased lateral flexion in the antero-posterior radiographs. (By courtesy of Mr E. N. Wardle.)

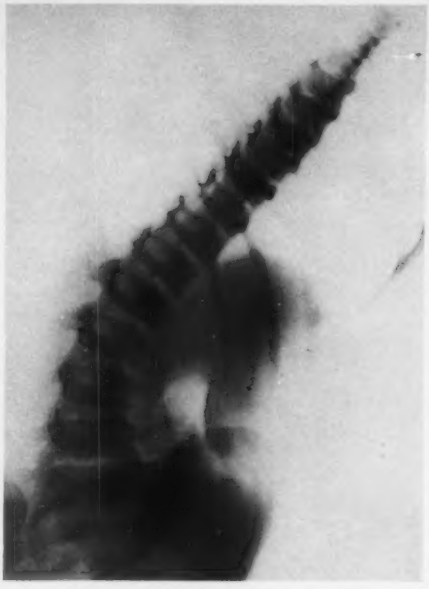


FIG. 42

FIG. 43

Figure 42—In this patient's spine there was a slight lateral scoliosis to the left in the thoraco-lumbar region. When this was corrected by right lateral flexion there was rotation to the right. This is the opposite of the direction of rotation which would be expected if the classical theory were true. Figure 43—Lateral flexion in the opposite direction, which increases the deformity, makes the rotation disappear.

SUMMARY

The principle of Occam's razor proves nothing. Nevertheless, it is possible to explain all the phenomena of severe scoliosis on the basis of a primary rotation deformity alone. The typical rotation type of scoliotic deformity can be reproduced artificially by fitting vertebrae together in an abnormal rotatory relationship without any element of lateral flexion. From this, certain mechanical factors inevitably come into play which must tend to increase the deformity. Above all, the forces responsible for progressive scoliosis are dynamic and active, not just passive. The spine readily compensates for a passive, non-progressive deformity such as a simple wedge vertebra. It is my belief that rotation is usually the dominant factor and that correction and control of severe scoliosis can only be achieved by concentrating on the rotation deformity. I am well aware that this is an old idea but its essential truth has been insufficiently appreciated in recent years and we have not faced its full implications. Failure to correct rotation invites recurrence. Conversely, even a slight reduction in rotation usually produces a marked cosmetic improvement, often out of all proportion to the radiographic appearances.

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THE OCCURRENCE OF PYROPHOSPHATE IN BONE

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The conditions required for the calcification *in vitro* of slices of rachitic rat cartilage have been extensively investigated, and attempts have been made to analyse the process in biochemical terms. The study of the role of enzymes in the calcification was initiated by Robison (1923), who discovered high concentrations of alkaline phosphatase in the pre-osseous cartilage of young rats. Robison suggested that a local increase in the concentration of phosphate ions produced by the hydrolysis of ester phosphates by phosphatase might be a factor in calcification. A difficulty which Robison recognised was that in body fluids the concentration of ester phosphate available as substrate for phosphatase action was low. Harris (1932, 1933), however, correlating older observations on the presence of glycogen in cartilage (especially marked in the hypertrophic cells of calcifying cartilage) with the then more recent knowledge of the biochemistry of glycolysis, suggested that "hypertrophic cartilage cells provide both the phosphatase enzyme described by Robison and glycogen which, on hydrolysis, yields hexose-phosphoric esters." The link between glycogen and phosphatase in cartilage was strengthened by the demonstration by Gutman and his co-workers (Gutman and Gutman 1941; Gutman, Warrick and Gutman 1942) that many of the enzymes of the glycolytic sequence of reactions are present in cartilage. Gutman also showed that *in vitro* calcification could be inhibited wholly or partly by compounds known to block certain reactions in the glycolytic sequence. He concluded that his experiments offered " an explanation for the accumulation and disappearance of glycogen at the site of calcification in cartilage and provide a potential source of phosphoric ester substrate for phosphatase."

The results of Robison and Gutman do not however provide a complete explanation of the calcification process, and several difficulties in the acceptance of the proposed mechanism have arisen. Cartilage slices have been shown to remain calcifiable *in vitro* after all enzymes have been destroyed. Rubin and Howard (1950) emphasised the importance in calcifiable cartilage matrix of material having properties resembling those of chondroitin sulphate. A local concentration of calcium ions in the matrix can be achieved by this material through a reversible ion-exchange process, and this may provide nucleation centres for the formation of crystals of bone salt. It is probably this portion of the calcification mechanism which survives in slices after the enzymes have been destroyed.

Although the evidence gathered by Robison concerning the association of phosphatase activity and calcification was impressive, more detailed information on the localisation of phosphatase in bone and cartilage obtained by modern histochemical techniques does not suggest any direct relationship between the enzyme and the deposition of bone salt. Phosphatase activity is greatest at the pre-osseous stage before calcification has begun, and the occurrence of glycogenolysis and high phosphatase levels in pre-hypertrophic cartilage cells may simply be indications of the intense metabolic processes accompanying cell differentiation (Pritchard 1952). Indeed, McLean and Urist (1955), after reviewing the evidence, stated that "one must conclude that all efforts to implicate phosphatase in calcification have failed, in spite of a most promising and apparently self-evident start thirty years ago."

Gutman himself was not convinced that the substrate for phosphatase was one of the phosphoric esters found in the course of the glycolytic sequence of reactions, and he suggested as an alternative that the phosphate was transferred to some unidentified phosphate acceptor in cartilage matrix before being finally deposited as bone salt (Gutman and Yu 1950). It is

probable, from analogy with the results obtained for other tissues, that the energy-producing reactions of glycolysis in cartilage are coupled to the synthesis of adenosine triphosphate (ATP) by reactions in which phosphate ester groups formed in the course of the glycolytic reactions are transferred directly to adenosine diphosphate (ADP)—for example:

$$\text{phosphopyruvic acid} + \text{ADP} \rightarrow \text{pyruvic acid} + \text{ATP}.$$

Gutman realised that glycolysis in cartilage might be coupled to the synthesis of ATP, and he examined carefully the possibility of ATP's being involved in *in vitro* calcification. However, he obtained consistently negative results in experiments in which ATP as the sole source of phosphate was added to slices *in vitro* (Gutman and Yu 1950). It is possible, in view of the results described below, that this may have been due to inhibition produced by impurities in the preparations of ATP employed.

Cartier (1951) demonstrated that the mineralisation of slices of pre-osseous cartilage of sheep embryo incubated in the presence of calcium was much more intense when ATP was used as the sole source of phosphorus in the medium than when inorganic or ester phosphate was used. In subsequent work Cartier and Picard (1955*a*, *b*, *c*, *d*) confirmed this preliminary report and investigated the nature of the deposit which was formed. They found that it differed from the deposit formed *in vitro* in rachitic rat cartilage slices and from bone salt in that a large proportion of its phosphorus content was in the form of pyrophosphate. A specific enzyme in the slices which formed pyrophosphate from ATP was demonstrated. The possible relationship of these results obtained *in vitro* with sheep foetal cartilage to the processes that take place in slices of rachitic rat cartilage and in the course of bone formation *in vivo* have been investigated, and the results are described in the present paper.

The presence of adenosine phosphates in cartilage was demonstrated by Albaum, Hirshfeld and Sobel (1952), but pyrophosphate has not been hitherto recorded as a component of normal osseous or pre-osseous tissue. In this paper the occurrence of small amounts of pyrophosphate in bone is described. Pyrophosphate, in amounts corresponding fairly closely to those occurring in normal bone, has also been found in the deposit formed in the course of the *in vitro* mineralisation of slices of rachitic rat cartilage when ATP is present in the medium. Our results are compared with those of Cartier and Picard.

METHODS AND MATERIALS

Preparation of tissues for analysis—The animals were killed by a blow on the head. Bone was dissected free from adherent tissue and split lengthwise, and the marrow was removed by a fine, powerful jet of water. Samples of the appropriate area of bone (0·1–0·3 g.) were blotted with filter paper, weighed, and extracted overnight at 2 degrees centigrade with 25 per cent (w/v) trichloroacetic acid (5 millilitres/g. tissue). The extraction of phosphates from small pieces of bone by this method is complete. The extract was centrifuged and the sediment washed once with 2·5 per cent (w/v) trichloroacetic acid. The combined supernatants were diluted with two volumes of water and passed through a small column of a cation-exchange resin (Zeo-Karb 215, H^+ form) in order to remove calcium, which was shown to be absent from the effluent by testing a neutralised portion with ammonium oxalate.

Mineralisation of cartilage slices *in vitro*—Young albino rats were kept on a high calcium, low phosphorus rachitogenic diet for three weeks from weaning. The animals were killed and the hypertrophic cartilage from the tibiae was removed. The slices (about 50 milligrams wet wt./flask) were incubated at 37 degrees centigrade for twenty hours in 20 millilitres of a medium containing calcium, $2{\cdot}0\times10^{-3}$M and orthophosphate, $1{\cdot}7\times10^{-3}$M, pH 7·4 (Dixon and Perkins 1952). In some experiments ATP (final concentration $1{\cdot}7\times10^{-3}$M) was substituted for orthophosphate. In the control flasks the slices were incubated in 0·154 M sodium chloride. At the end of the incubation period the slices were removed from the flasks, blotted, weighed and extracted by the method described above. Because of the small amount of tissue used

it was necessary to concentrate the decalcified extracts by evaporation *in vacuo* at 0 degrees centigrade in order to obtain a quantitative measure of the pyrophosphate present.

Separation and estimation of phosphates—Phosphates in the decalcified extracts were separated by paper chromatography using the techniques of Eggleston and Hems (1952) and Krebs and Hems (1953). Orthophosphate was separated from other phosphates on the folded chromatogram by a short ascending run in diethyl ether, 90 per cent formic acid (90 : 60). The paper was dried at room temperature and the end of the limb containing the orthophosphate area cut off. Other phosphate compounds were separated by a descending run in isobutyric acid, ammonia, versene. After drying, the sheets were examined under ultra-violet light and the phosphates localised and estimated by the method of Eggleston and Hems (1952). By these techniques the lower limit of the amount of phosphate that can be separated and estimated is about 0·5μ g.

Total phosphate was estimated by a modification of the method of Fiske and Subbarow (1925).

Estimation of phosphatase and pyrophosphatase activity of rachitic rat cartilage—An estimate of the activity of these enzymes under conditions comparable to those employed in the mineralisation experiments was required. The cartilage, obtained as described above, was ground with distilled water to give a fine suspension (4 per cent. w/v), and this preparation was used in order to avoid artefacts from incomplete extraction of the enzymes. The inorganic phosphate liberated on incubating the enzyme preparation with substrate (0·013 M) for fifteen minutes at 37 degrees centigrade and pH 7·4 veronal buffer (0·0075 M) was estimated by the method of Fiske and Subbarow (1925). The tissue suspension in the control flasks was inactivated by heating for ten minutes in a boiling water bath. Sodium β-glycerophosphate was the substrate in the phosphatase estimations. For pyrophosphatase, sodium pyrophosphate was used and the substrate remaining at the end of the incubation period was removed by precipitation with $MnCl_2$ (Kornberg 1950) before carrying out the phosphate estimation.

TABLE I

PYROPHOSPHATE CONTENT OF THE LONG BONES OF RATS AND RABBITS

Animal	Age (*in weeks*)	Bone parts	Pyrophosphate (per cent wet weight tissue)	Pyrophosphate (per cent total phosphate)
Rat	14	Cortex	0·028	0·5
		Ends	0·070	1·2
	3	Cortex	0·050	0·56
		Ends	0·021	0·84
	4	Cortex	0·024	0·25
		Ends	0·053	1·4
Rabbit	10	Cortex	0·053	0·68
		Metaphysis	0·019	0·23
	10	Cortex	0·067	0·73
		Metaphysis	0·021	0·30
	14	Cortex	0·050	0·57
		Metaphysis	0·025	0·31

RESULTS

Orthophosphate and pyrophosphate were the only phosphates detected by chromatography of the bone extracts and no nucleotides were found in any of the preparations. Pyrophosphate was present in every sample examined and Table I shows the amounts found by quantitative

analysis of different areas of rat and rabbit bone. In the case of the rat the tibia and femur were divided into the cortical bone of the shaft and the bone ends, which include both epiphysial and metaphysial regions. Samples of diaphysial cortex and metaphysis were taken from the rabbit bones. The results show that a small but definite proportion of the total phosphate was present as pyrophosphate in each sample, the highest value being found in the rat bone ends.

A more detailed examination of the distribution of pyrophosphate in rat bone was carried out. The tibiae of three rats (four weeks old) were divided into five regions (listed in Table II) and pooled, and the proportion of pyrophosphate in each region was estimated. The highest values found were in the epiphysial regions, and, as in the rabbit (*cf.* Table I), the metaphysial cancellous bone contained a lower proportion of pyrophosphate than the diaphysial cortex.

The techniques of extraction and estimation were checked by the addition of pyrophosphate to bone samples. Recovery was within 95–105 per cent. Other experiments showed that no pyrophosphate was formed from inorganic phosphate in the course of the procedures employed. The bone marrow was removed routinely but in one experiment where this step was omitted no alteration in the pyrophosphate content of the sample was found.

TABLE II

PYROPHOSPHATE CONTENT OF VARIOUS REGIONS OF RAT TIBIA
(three animals)

Bone region	Pyrophosphate (per cent total phosphate)
Diaphysial cortex	0·55
Metaphysial cancellous bone . . .	0·19
Zone of primary calcification . . .	0·27
Epiphysial plate cartilage . . .	0·89
Epiphysial cortex including articular surface	1·14

Calcification of cartilage *in vitro*—The deposition of calcium salts which occurs on incubating slices of cartilage from rachitic rats in calcifying solutions has often been used in studies of factors which might, by analogy, be expected to influence calcification *in vivo*. Under certain conditions the presence of pyrophosphate, in amounts comparable to those found in normal bone, can be demonstrated in the deposit formed by such preparations. The results obtained in media containing calcium and either inorganic phosphate or ATP as the source of phosphorus are shown in Table III. In both media the total phosphate in the slices, compared with that in control slices incubated in saline, rose. The proportion of pyrophosphate in slices incubated in the presence of inorganic phosphate fell, presumably due to dilution of pre-existing pyrophosphate by freshly deposited orthophosphate. Incubation in the presence of ATP, on the other hand, caused a rise in the pyrophosphate content of the slices and in the proportion of the total phosphate present as pyrophosphate. It is estimated from the results that about 5 per cent of the phosphate deposited was in the form of pyrophosphate.

The disappearance of ATP from the medium during the course of incubation of the cartilage slices was studied. The results are shown in Figure 1. After five hours' incubation ATP had disappeared almost completely and the only breakdown product that could be identified, apart from a small amount of ADP in the initial stages of incubation, was orthophosphate. No pyrophosphate was found in the medium at any stage, whereas the deposit

formed in the slices contained a proportion of pyrophosphate which rose to a maximum after about two hours of incubation. It appears therefore that the reaction which leads to the formation of the pyrophosphate in the deposit must be localised within the slices since there is no evidence of the accumulation of pyrophosphate in the medium at any stage.

TABLE III

PYROPHOSPHATE CONTENT OF HYPERTROPHIC CARTILAGE OF RACHITIC RATS AFTER INCUBATION IN VARIOUS MEDIA
(twenty hours at 37 degrees)

Experiment number	Incubating solution	Phosphate (per cent wet weight tissue)	Pyrophosphate (per cent wet weight tissue)	Pyrophosphate (per cent total phosphate)
1	NaCl	0·67	0·0039	0·58
	Ca+P	1·05	0·0018	0·17
	Ca+P+fluoride	1·34	0·0040	0·30
2	NaCl	1·06	0·0051	0·48
	Ca+ATP	2·43	0·066	2·7
	Ca+ATP+fluoride	1·88	0·045	2·4

Pyrophosphatase activity in cartilage—Perkins (1954) showed that in estimations carried out at pH 7·4 growing regions of bone in the rat and rabbit have considerable pyrophosphatase activity. This enzyme catalyses the hydrolysis of pyrophosphate to orthophosphate. The results in Table III show that hypertrophic rachitic cartilage contains approximately twice as much pyrophosphatase as glycerophosphatase activity when measured under the same conditions. In contrast to these findings, Cartier *et al.* (1955*a*) stated that the pyrophosphatase

TABLE IV

PYROPHOSPHATASE AND GLYCEROPHOSPHATASE ACTIVITIES OF RACHITIC RAT CARTILAGE
(Incubated fifteen minutes at 37 degrees in veronal buffer, pH 7·4.
Results expressed as mg. phosphate liberated/mg. tissue)

Experiment number	Substrate	
	Pyrophosphate	β-glycerophosphate
1	7·9	4·0
2	6·9	3·3
3	6·0	3·0

activity of sheep embryo cartilage used in their experiments was only about one-quarter of the glycerophosphatase activity. These results provide an explanation for the much smaller proportion of pyrophosphate in the deposit formed by rachitic rat cartilage compared with that in the foetal sheep cartilage studied by Cartier.

DISCUSSION

It is interesting to compare the results presented here with those recently published by Cartier and Picard. These authors confirmed our observation that pyrophosphate is present in small amounts in normal bone, while our results confirm their findings of pyrophosphate as a component of the deposit formed by the *in vitro* mineralisation of cartilage slices in media

containing ATP and also provide evidence in support of their theory that this pyrophosphate is formed by an insoluble ATP-pyrophosphatase. The large difference in the proportion of the total phosphate deposited as pyrophosphate by rachitic rat cartilage (approximately 5 per cent) and by sheep embryo cartilage (approximately 80 per cent) (Cartier and Picard 1955*c*) is almost certainly due to the difference in the inorganic pyrophosphatase activity of the two tissues. The activity of this enzyme is considerable in rat cartilage whereas it is very low in

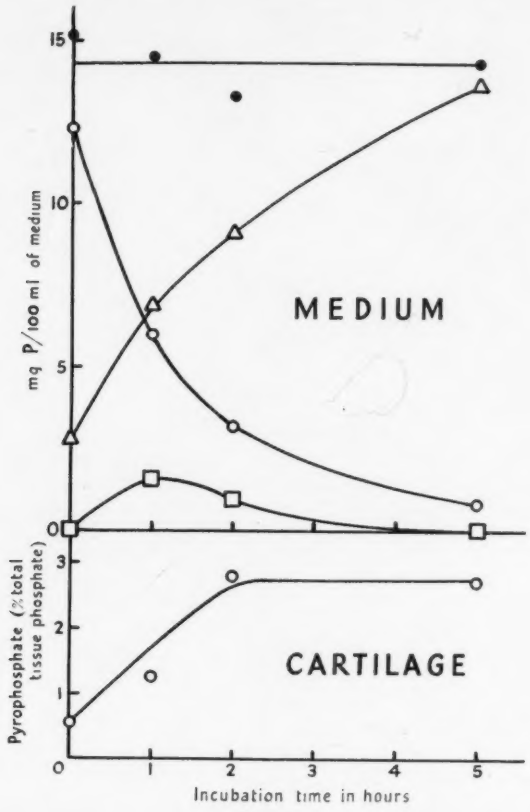

FIG. 1

Changes in distribution of phosphorus components during incubation of rachitic cartilage slices in a medium containing Ca and ATP.

Key: Medium: O——O = ATP; □——□ = ADP; Δ——Δ = inorganic orthophosphate; ●——●=total phosphorus (sum of fractions).
Cartilage: O——O = pyrophosphate.

sheep embryo material. The fact that only small residual amounts of pyrophosphate are found in rachitic rat cartilage deposit and in normal bone salt does not minimise the possible importance of the ATP-pyrophosphatase reaction in the initial mineralisation of these tissues.

Our findings are therefore consistent with the theory of Cartier and Picard that the formation of pyrophosphate from ATP may play an important role in initiating the deposition of phosphate in bone. The use of sheep embryo cartilage enabled these authors to isolate the ATP-pyrophosphatase reaction and gave a deposit consisting predominantly of calcium

pyrophosphate. The deposit formed by rachitic rat cartilage which, like normal hypertrophic cartilage, contains inorganic pyrophosphatase as well as ATP-pyrophosphatase, is more closely related in composition to bone in that it contains only relatively small amounts of pyrophosphate.

SUMMARY

A small proportion of the total phosphate in normal bone salt occurs in the form of pyrophosphate. The deposit formed *in vitro* on incubation of rachitic cartilage with a calcifying medium does not contain pyrophosphate unless ATP is added to the medium, in which case the proportion of pyrophosphate is of the same order as that found in normal bone.

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IN MEMORIAM

GROUP CAPTAIN C. J. S. O'MALLEY
C.B.E., M.B., B.S., M.R.C.S., L.R.C.P.

1901–1958

Charles James Sidney O'Malley, who died suddenly on January 25 at the age of fifty-seven, was medical director of two important rehabilitation centres in London, Regional Adviser to the Ministry of Health and to the Ministry of Labour and National Service, Deputy Director of United Nations training courses in Sweden, Finland and Denmark, and Consultant Adviser on medical rehabilitation to the World Veterans Federation. These responsible duties, which he discharged with human understanding, sound wisdom and good commonsense as well as joyful optimism and bubbling enthusiasm, were the direct outcome of his great work throughout the last war when he directed the mental and physical recovery of thousands of pilots, navigators, air-gunners and ground staff who had been disabled by fearful injuries. This was indeed his finest hour.

From the earliest days of the Battle of Britain, the raiding of Germany, the Desert Campaign, the invasion of Italy and finally of Europe, in consequence of enemy action, mid-air collision and crash-landing, these intrepid and brave young men suffered not only multiple injuries—even as many as fifteen or twenty major fractures and dislocations, perhaps of all four limbs and spine, with nerve injuries, wounds and burns—but usually also the sense of anxious frustration, hopelessness and fear. Yes, even these fearless men often feared their future in the worrying dark hours of night. Despite all this no less than 92 per cent of pilots and air-crews returned to flying duty; 68 per cent resumed full operational activities; and 84 per cent of engineers, electricians and mechanics and other ground technicians returned to their trades.

Born in Melbourne, Australia, son of the late Captain O'Malley, D.S.O., James O'Malley was educated at Wellington College and St Thomas's Hospital Medical School, where he qualified in 1925. In these early days he was a happy, enthusiastic and boisterous medical student, a formidable scrum-half in the St Thomas's rugby football team, and, but for his joining the Royal Air Force in 1926 and being sent forthwith overseas, would almost certainly have had his Irish national football cap. After service in many parts of the world he was appointed Senior Medical Officer in one of the Royal Air Force groups in England. When war broke out he was at the Officers' Convalescent Hospital at the Palace Hotel, Torquay, until it was bombed. Even then he infused into the older notion of convalescence a new spirit of active recovery. He was Principal Medical Officer in the Desert Air Force in Sicily and Italy, and organised the air

evacuation of 21,000 casualties. Thereafter he was posted as Commanding Officer to the rehabilitation unit established at Loughborough College, where extensive playing fields, gymnasia, recreation rooms and swimming pool formed the physical basis of treatment after surgical measures at Royal Air Force General Hospitals. He shared a very large part in the development of all seven rehabilitation centres that were established.

Even with a background of fairly rigid Service discipline he quickly found the right approach for men whose spirit as well as body was hurt and for whom a bold independence was essential. He always remained approachable and sympathetic as a listener. Patients were made to feel that they were of individual importance, that life was worth living and full of purpose, no matter what disabilities had to be overcome or accepted. For all his convivial friendship and benevolence, making him the life and soul of every party, on or off duty, he commanded discipline by inspiring loyalty, friendship and confidence. His eager enthusiasm and happy optimism were infectious. Every patient as well as every orderly, nursing sister, physiotherapist and young surgeon knew he was to be trusted absolutely and obeyed him happily and willingly.

These qualities together with industry and downright matter-of-fact sense accounted for brilliant success when similar principles were applied to the treatment of disablement in industry. In this most important field of medicine he was an international leader.

He is survived by a widow and two young married daughters; and is remembered affectionately and warmly as Jamie by many thousands now dispersed throughout the world for whom a new life was born. R. W.-J.

HAYMAN ISAAC MAISTER, F.R.C.S.

1904–1958

H. I. Maister, who died suddenly at Port Elizabeth in January, was one of the leaders of orthopaedic surgery in South Africa. For over ten years he pioneered the development of orthopaedic services and the care of cripples in the Eastern Cape. His idealism and selfless devotion gained wide respect and acknowledgment from the various Medical Associations and Councils with which he identified himself in his own country, and from the British Orthopaedic Association, which elected him a Fellow.

After early education in Pietermaritzburg he came to England, qualified in medicine in 1927, and gained the Fellowship of the Royal College of Surgeons of Edinburgh. He trained in Birmingham at the Royal Orthopaedic Hospital as Registrar and Chief Assistant to the late Naughton Dunn, and was then assistant to F. G. Allen, at whose wedding he was best man. We saw much of him at the Robert Jones and Agnes Hunt Orthopaedic Hospital in Shropshire, and at meetings of the British Orthopaedic Association. He was the very first holder of the Robert Jones Golf Cup given by the late Rowley Bristow for competition on the occasions of the Annual meetings. Soon after the outbreak of war he took charge of a military orthopaedic centre in Great Britain, and was later posted overseas as Lieutenant-Colonel in charge of surgical units in India and Burma.

Those of us who visited Maister in the orthopaedic centres he had established at Port Elizabeth and Uitenhage quickly recognised the success he had achieved in a part of South Africa where all social services were developing rapidly. He was a member of the National Council for the Care of Cripples, and President of the Cape Midlands Branch of the Medical Association of South Africa. Above all he will be remembered as a kind, gentle, considerate man, unassuming even to the extent of hiding his light under a bushel, great friend to many wounded servicemen, disabled people and crippled children, and a respected colleague throughout the Union of South Africa and Great Britain. R. W.-J.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

TENTH ANNIVERSARY OF THE FOUNDATION OF THE BRITISH VOLUME THE JOURNAL OF BONE AND JOINT SURGERY

At an informal ceremony on February 14, 1958, to mark the tenth anniversary of the foundation of the British Volume of the *Journal of Bone and Joint Surgery*, the Editor, Sir Reginald Watson-Jones, was presented with a silver salver engraved with the names of past and present members of the Editorial Board. Among those present were the two past Chairmen of the Editorial Board, Sir Harry Platt and Professor George Perkins. Other distinguished guests were Sir Gordon Gordon-Taylor and Lady Fairbank. The photographs shown on the facing page were taken during the ceremony.

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

A meeting was held at the National Institute for Research in Dairying, Shinfield, Reading, on June 4, 1957, with Professor H. D. Kay in the chair.

Resorption and repair of the skeleton in the ewe—*Mr D. Benzie, Mr A. Dalgarno, Dr J. Duckworth* and *Dr R. Hill* (Bucksburn, Aberdeenshire). Resorption of the skeleton during pregnancy and lactation in ewes fed on diets containing different amounts of calcium and phosphorus had been assessed by comparing the ash content of individual bones or of the whole skeleton of animals killed in early pregnancy with those of animals killed at mid-lactation. Similarly repair had been assessed by comparing the values from these animals with values obtained from ewes killed four months after mid-lactation. Radiological observations on the skeletons were also made. When total skeletal resorption was slight to moderate the shafts of the radius and metacarpal (principally cortical tissue) were not significantly affected while the cervical vertebrae (principally cancellous tissue) were markedly resorbed. When total resorption was severe the shafts of the radius and metacarpal, though affected less than the cervical vertebrae, were significantly resorbed. Repair of the cervical vertebrae took place readily, but repair of the shafts of the radius and metacarpal took place very slowly, if at all, even when the diet contained adequate amounts of calcium, phosphorus and vitamin D throughout the repair period. In general, radiological observations supported the results of ash analyses.

Some effects of bone fracture in hens—*Dr T. G. Taylor* and *Dr J. H. Moore* (Reading) recalled that Landauer and Zondek (Amercian Journal of Pathology, **20,** 179, 1944) had considered that the variations in the amount of medullary bone formed in the different bones of the avian skeleton under the influence of sex hormones were related to differences in their blood supply. The authors attempted to test this hypothesis in the domestic fowl. The blood supply to one metatarsus, a bone which does not normally contain medullary bone, was augmented by fracture, and the fractured bone was compared with the unfractured one as a control. Eight pullets were used in this experiment, four laying and four that had not yet started to lay; one from each group was killed five, seven, ten and fifteen days after the operation. In all the laying birds and in three of the four non-laying ones, medullary bone was present in the fractured bone but not in the unfractured one. (Only one of the non-laying birds had a completely quiescent ovary at slaughter.) The tibia and femur were weighed; except in one bird, the bones on the fractured side weighed less than on the unfractured; and it appeared that the cortical bone but not the medullary had suffered the loss.

The effects of decalcifying agents on the staining properties of bone and cartilage—*Miss Noelle Stinson* (London) had tested the staining qualities of rat tibiae decalcified for various lengths of time in nitric acid (pH 0·8), formic acid/sodium citrate (pH 2·3) and ethylenediamine-tetraacetic acid (EDTA) (pH 7·0) were compared. Material decalcified for six days in EDTA gave the best staining. *Azure II and toluidine blue.* Cartilage metachromasia was little altered after EDTA decalcification. Nitric acid and prolonged formic/citrate decalcification greatly reduced metachromasia. *Periodic-acid Schiff technique.* Staining was unaltered by any of the conditions used. *Haematoxylin and eosin.* Loss of cartilage basophilia followed lengthy decalcification in all three agents. Differentiation between

FIG. 1

FIG. 2

Figure 1—Sir Harry Platt and Professor George Perkins, past Chairmen of the British Editorial Board. Figure 2—Sir Reginald Watson-Jones, British Editor, receiving a presentation salver from the present Chairman, Professor Sir Walter Mercer.

FIG. 3

Left to right: Professor J. Trueta, Mrs Pulvertaft, Mr Guy Pulvertaft, Mr Norman Roberts, Professor Sir Walter Mercer, Sir Reginald Watson-Jones.

FIG. 4

FIG. 5

Figure 4—Mr Charles Macmillan and Sir Gordon Gordon-Taylor. Figure 5—*Left to right:* Miss Jean Barnes, Mr H. Jackson Burrows, Professor Sir Walter Mercer, Mr Philip Wiles.

marrow, bone and red blood cells was relatively simple even after prolonged decalcification in EDTA, but was almost impossible with the two acid agents because of loss of cytoplasmic and nuclear basophilia in the marrow and bone cells. *Eosin-azure*. Loss of matrix basophilia was less marked. Marrow elements and bone cells were again satisfactory only after EDTA. *Conclusions*—Nitric acid had marked ill-effects on the staining qualities of bone and cartilage even in a short time. The formic/citrate mixture was satisfactory only for periods much shorter than those required to decalcify human cortical bone. With EDTA the staining intensity was little altered even after prolonged decalcification.

The determination of ionised calcium in human plasma—*Dr G. Alan Rose* (London) described the estimation. Thirty-five millilitres of heparinised blood were centrifuged under paraffin and the plasma transferred to an ultrafiltration shell (Membranfilter Gesellschaft, Germany). The plasma was submitted to nearly 1 atmosphere pressure without gaseous contact, and the outer chamber contained moistened 5 per cent carbon dioxide in oxygen. Ultrafilterable calcium was 6–6·4 milligrams/100 millilitres, independent of the degree of ultrafiltration. Ionised calcium was determined by the method of Raaflaub (Hoppe-Seyler's Zeitschrift für physiologishche Chemie, **288**, 228, 1951). Exactly 0·1 millilitre of 30·2 milligrams per cent aqueous murexide was added to 2 millilitres of ultrafiltrate, and moist 5 per cent carbon dioxide in oxygen was bubbled through until there was no further colour change. Extractions at 470 $m\mu$ were compared with calcium standards of the same ionic strength and bicarbonate content (measured by pH when in equilibrium with 5 per cent carbon dioxide). In seven normals ionised calcium in the ultrafiltrate was 5·65–6·20 milligrams/100 millilitres complexed calcium in the ultrafiltrates, by difference, was 0·15–0·51 milligrams/100 millilitres. A full account of this work appears elsewhere (Rose, G. A., 1957: Clinica Chimica Acta, **2**, 227).

Radiation damage in the upper half of the tibia after a single injection of ^{90}Sr and an estimation of the radiation dose received—*Dr Maureen Owen, Dr H. A. Sissons and Dr Janet Vaughan* (Oxford and London) had given a single high dose of ^{90}Sr (500–1,000 μc/kc.) to rabbits aged two days, six to eight weeks and one year. Only the middle group showed gross bone damage, although all died at six to eight months after injection. *Six to eight weeks group, upper half of tibia.* Most damage was in the regions of maximum Sr retention, i.e., the posterior wall at the level occupied by the plate when injected. There was gross failure of cartilage resorption. The residual cartilage stained normally. Cartilage formed above the level of ^{90}Sr uptake was abnormal, having a thickened appearance and diminished staining properties. Abnormal Haversian systems lay between the unresorbed cartilage remnants. Measurements of the radiation dose in this region had been made. With a dose of 600 μc/kg., after one and thirty days the radiation doses in the tibial plate were 800 and 560 rads/day respectively. The degree of failure of resorption varied from animal to animal; hence so did ^{90}Sr retention and consequent radiation dose. (Owen, M., Sissons, H. A., and Vaughan, J. (1957): British Journal of Cancer, **11**, 229.)

A histological study of Ranvier's ossification groove in the long bones of foetal and post-natal rats—*Dr C. W. M. Pratt* (Cambridge) had investigated the groove of Ranvier at the distal end of rat femora. In a seventeen-day foetus the perichondrium did not reach the epiphysis and the groove was in open communication with the surrounding mesenchyme. By nineteen days this gap was closed. The groove fibres might penetrate the epiphysial cartilage for some distance, in which case it appeared that appositional growth was marked.

Elsewhere the fibres blended with the matrix between the superficial epiphysial cells producing a lattice-like appearance. Periosteal fibres corresponded to Schafer's " longitudinal osteogenic fibres." The fibres were crossed at right angles by other fibres in regions of tendon or ligament attachment (Ranvier's "fibres acriformes"). Mesenchymal cells in a seventeen-day groove later formed fibroblasts, which in turn gave both chondroblasts and osteoblasts. A fibrous network on the groove floor limited the cartilage, and was continuous with the fibres of early perichondrial bone. Late perichondrial bone became deposited on it. There was no evidence that the longitudinal fibres of the groove were continued into either periosteal or perichondrial bone.

EAST ANGLIAN ORTHOPAEDIC CLUB

A meeting of the East Anglian Orthopaedic Club was held on May 25, 1957, at the Norfolk and Norwich Hospital, Norwich.

Stapling—*Mr R. C. Howard* showed cases in which stapling had been used for conditions other than epiphysial arrest for genu valgum which he had demonstrated previously. Staples were used for arthrodesis and for mechanical fixation of fractures. He had found that the usual stainless steel staples had often broken, and he was now using a new model made of Vitallium. New epiphysial sites that had been tackled were the femoral epiphysis to prevent flexion deformity, the lower end of the tibia to prevent valgus deformity and (unsuccessfully) the lower end of the humerus to prevent

cubitus varus. Attempts to treat adolescent hallux valgus in this way had been unsuccessful. In arthrodesis he had found stapling useful in the foot, shoulder and carpo-metacarpal joints. He had also found it a useful means of fixing friable ligaments, as in supraspinatus tear.

Congenital dislocation of hip—*Mr J. G. Taylor* discussed the late results of treatment of congenital dislocation of the hip. He considered that the results were still not very good but that they might be improved, especially if anteversion of the neck were considered more seriously. He said that at least 52 per cent of patients showed this deformity and very possibly more. The régime he advocated was: 1) traction in a double abduction frame for two to three weeks ; 2) arthrography to determine whether the limbus was displaced, in which event it should be removed. The limb should be fixed in a position of medial rotation and abduction for four weeks; then at a second operation a lateral rotation osteotomy through 60–80 degrees should be carried out and the fragments fixed with a small plate. Plaster should be continued for six or seven weeks. This routine was giving good results so far and shortened the duration of treatment considerably.

Hyperextension of the knee associated with early fusion of the front of the tibial epiphysis—*Mr W. Kellock* showed two cases of hyperextension of the knee associated with early fusion of the front of the tibial epiphysis and subsequent distortion of the tibial plateau. Treatment by plaster cylinder was advocated, and there was an interesting discussion.

Artificial hip joint—*Mr G. K. McKee* demonstrated the modification of his artificial hip joint and showed a patient in whom it had been used successfully. He showed a film of the operation.

Plastic spinal support—*Mr G. K. McKee* demonstrated a method of making a plastic spinal support that could be moulded on to the patient without the delay of measurement and making by an instrument firm.

Cervical support—*Mr McKee* also showed the fitting of a cervical support made by Messrs Sillis, Strudwick and Co. Ltd.

A further meeting of the club was held at the Newmarket General Hospital on November 30, 1957.

Rheumatoid arthritis—At the invitation of *Mr Jamieson*, *Dr I. P. Williams*, radiologist to the hospital, showed radiographs of hands in rheumatoid arthritis. He pointed out the periosteal reaction on metacarpals present in 10 per cent of cases. In time this leads to the changes in the shape of bones. He also showed the presence of soft-tissue swellings about the metacarpo-phalangeal joints and about the ulnar styloid, even leading to erosion of this process.

Changes in the femoral capital epiphysis—*Mr E. S. Jamieson* discussed the changes in the femoral capital epiphysis seen in children during recovery from tuberculous arthritis. He had noticed and showed films of a mantle of bone appearing over the head twelve to eighteen months after the onset of symptoms, continuing for up to three years before it began to disappear. He suggested this might be the result of a spurt of bone forming activity after successful control of infection in the presence of increased blood supply and increased stimulation; an alternative possibility was that it was the result of increased laying down of bone from articular cartilage that was deriving good nourishment from synovial fluid.

Forearm injuries—*Miss M. Welply* showed three cases of forearm injuries, two from cut glass with tendon and nerve section, and one from crushing by machinery, with tearing rather than cutting of the median nerve. After suture in the first two cases a good functional result was obtained. It was surprising how little sensory loss remained even in the last case.

Monteggia fractures—*Mr K. Basappa* showed four cases of Monteggia fractures in children. Although the prognosis in these fractures is often thought to be poor, in these cases the results were excellent.

Short cases—Among other cases shown by *Miss M. Welply* were 1) A child with tuberculous talus eventually treated by scraping, with preservation of good movement. 2) Hyperextension injury of the wrist with normal radiographs. The pain continued and eventually the wrist was explored. Subluxation of the lunate bone was found with rupture of the anterior ligament of the wrist. 3) Acromio-clavicular dislocation treated by screw from clavicle to coracoid. The result was good. Much difference of opinion was expressed on the treatment of this injury.

SOUTH-WEST ORTHOPAEDIC CLUB

The South-West Orthopaedic Club met at the Great Western Unit of the Gloucester Royal Hospital on November 23, 1957. The Chairman was Mr L. Henry and fifty-five members were present.

Quadriceps-plasty of the knee—*Mr Brian Thomas* showed two patients subjected to quadriceps-plasty seven and five years ago for stiff knee complicating fracture of the femur. One patient, an ex-soldier,

had been wounded by a shell fragment in 1943, sustaining a fractured right femur. This was followed by a discharging sinus and later sequestrum formation. After sequestrectomy and healing of the sinuses the quadriceps-plasty was performed. Before operation flexion was possible through only 15 degrees; after operation, although there was an extension lag of 10 degrees, the range of flexion was only about 20 degrees short of the full range. The patient now worked on Post Office duties, climbed telegraph poles and also played football. The other patient was a man of thirty-five, now employed as a tyre inspector, who sustained a compound fracture of the left femur in a motor cycle accident. There was a sequestrum formation with sinuses which required surgery to bring about healing. Before quadriceps-plasty only 35 degrees of flexion was possible. Afterwards there was a 20 degrees' lag of extension with a range of movement from 180 to 60 degrees. The technique used had been that described by Thompson (Journal of Bone and Joint Surgery, **26**, 366, 1944). Mr Thomas used a tourniquet to ensure a bloodless field. This was applied high up on the thigh and was held in position by a Steinmann pin driven into the femur. At the completion of the operation a groin to ankle plaster was applied for ten days; then the leg was placed in a Fisk splint. The splint was retained until 90 degrees of flexion had been obtained. The lag in extension at that time was 45 degrees, which persisted for about a year. The present satisfactory state of the patients had been achieved only after a long interval.

Butler's operation for hallux valgus—*Mr J. Bourdillon* showed four patients with hallux valgus treated by this operation, which consisted of a spokeshave to remove the protruding part of the metatarsal head, and osteotomy of the base of the proximal phalanx, to realign the great toe. The advantages that Mr Bourdillon claimed were that the full length of the toe was preserved and that more movement was recovered and this more rapidly than after other procedures. The after-treatment was a plaster toe-cap for fourteen days, then exercises and faradic foot baths. The patients were allowed up on the third day after operation walking on their heels. The operation was not indicated when severe osteoarthritis was present, but it had a place in the treatment of hallux valgus in young people. All the patients had a good cosmetic result with good range of movement and expressed satisfaction with the operation.

Arthrodesis of the ankle by Gallie's method—*Mr Bourdillon* recalled that the operation consisted in placing two cortical tibial grafts three inches long and one inch wide through two apertures cut in the lower part of the tibia and driving them into the talus. The ankle was immobilised in plaster for thirteen weeks after the operation. Two patients were shown: a woman of sixty-seven with severe osteoarthritis of the ankle after an old Pott's fracture, and a man of seventy-six with a tuberculous ankle and healed sinuses over the lateral malleolus. Sound bony fusion had been obtained in each case.

Posterior approach for operative reduction of dislocated lunate bone—*Mr Bourdillon* said that it was easy to secure reduction by this approach and it led to no further damage to the blood supply of the lunate bone. A longitudinal incision was made on the dorsum of the wrist, the extensor tendons were retracted to one side, the capsule was opened, and with the wrist palmarflexed the lunate bone was rotated back into position with a small hook. The first patient, a storeman, had dislocated his lunate bone in 1956. Two unsuccessful manipulations were performed elsewhere, and operative reduction was carried out three weeks after the injury. There was now full range of movement in the wrist and avascular necrosis had not developed so far. The patient, however, did not do heavy work. The second patient, a farm worker, also sustained a dislocation of the lunate bone in 1956. Attempted manipulative reduction was unsuccessful; so operation was undertaken. There was limited dorsiflexion of the wrist and pain on performing heavy work. Recent radiographs showed avascular changes.

Subluxation of both patellae—*Mr Bourdillon* showed a woman of thirty-five with subluxation of both patellae. Transplantation of the patellar tendon had been performed on both sides, and, although that on the right side was successful, on the left side the patella still became displaced. The patella was later excised, but thereafter the knee remained unstable and the tendon slipped over the lateral femoral condyle. In an attempt to "tighten" the knee a subtotal synovectomy was carried out, but after a month in plaster the patient regained full movement in the course of a week and the knee was as unstable as before. Mr Bourdillon invited suggestions for further treatment. The feeling of those who spoke was that the patient should either wear a jointed caliper or should submit to arthrodesis of the knee.

Flexor-extensor tendon transplant for claw toes—*Mr J. F. H. Stallman* showed four patients in whom the results of this operation were excellent.

Osteogenic sarcoma of the femur—*Mr Stallman* showed a policeman of thirty-nine who in 1949 had the right leg amputated through the base of the trochanters of the right femur for osteogenic sarcoma of the femur in its lowest third. The diagnosis had been confirmed by members of the Bristol Bone

Registry although their opinion had not been unanimous. A satisfactory prosthesis had been supplied and the police constable was now engaged on station duties. There had been no evidence of recurrence so far.

Chondrosarcoma of the blade of the scapula—*Mr Stallman* showed a man of thirty who had developed a swelling of the left shoulder blade thirteen years ago. The swelling proved to be a chondrosarcoma and the body of the scapula was exicsed. Recurrences necessitated further operations, the last three years ago when the axilla was involved. The man was now fit and well, with only slight disability, and was free from further recurrence. He had about three-quarters of the full range of movement at the shoulder and was able to do heavy work as a market gardener.

Syme's amputation for crushed foot—*Mr Stallman* showed an excellent three-year result from a Syme's amputation in a man of twenty. The man was now working as a hospital porter.

Subtrochanteric osteotomy for slipped femoral epiphysis and for infantile coxa vara—*Mr L. Henry* had performed this operation on three patients with slipped epiphysis when the displacement could not be corrected by gentle manipulation. After the operation the hips had been immobilised in plaster spicas for three months. All the patients walked very well with only a slight limp. There was a good range of movement in flexion, extension and abduction, but rotation was limited. The operation had also been performed on a patient with bilateral infantile coxa vara. This patient now walked normally and had almost full movement in both hips.

Relapsing talipes equino-varus—*Mr Henry* showed a boy of nine years. Six years after all forms of correction had been attempted both feet exhibited a severe equinus deformity with incurved heel and a convex outer border of the feet. As the boy was too young for a wedge tarsectomy, Mr Henry devised the following procedure: a posterior incision was made on one side of the tendo calcaneus, which was lengthened by Z-plasty. The posterior capsule of the ankle joint was opened and the tibio-fibular ligament was divided. The mortise was thus widened, allowing the talus to dorsiflex, with correction of the equinus deformity. The varus deformity of the heel was then corrected by a wedge osteotomy of the calcaneum. Both feet were now plantigrade. *Mr Norman Capener* said that he had obtained dorsiflexion of the talus in a similar case by removing small portions of bone from each side of the talus, thus reducing its width.

Extra-articular subtalar fusion for plano-valgoid feet—*Mr Henry* showed an example of Grice's operation (insertion of a bone graft into the sinus tarsi) in a girl of sixteen who had severe mobile plano-valgoid feet. The deformity was now well corrected and the patient was well pleased with the result.

Fracture of odontoid process of the axis—*Mr Henry* described a fracture of the odontoid process of the axis vertebra, with posterior displacement of the odontoid peg and lateral dislocation of the atlas. This had occurred in a patient of forty-eight and had not been accompanied by neurological disturbance. The treatment had been skull traction for six weeks, followed by a Minerva jacket. Although the posterior dislocation was corrected it was not possible to reduce the lateral dislocation of the atlas. The patient now had a very stiff neck but had no neurological symptoms.

Secondary hypernephroma in the calcaneum—*Mr Henry* showed a woman of forty-five who had presented with pain in the right calcaneum after an injury of her ankle. Radiographs revealed a cystic area in the bone and this on biopsy proved to be a secondary neoplasm, which the pathologist considered might have arisen from a kidney tumour. A pyelogram revealed a hydronephrosis in one kidney. This was explored and a small neoplasm was found in the ureter near the pelvis. After nephrectomy and a below-knee amputation of the affected leg the patient made a complete recovery and was now well twenty years afterwards.

" Stove-in chest "—*Mr Henry* showed the radiographs and described a case of " stove-in chest " previously reported by him (British Medical Journal, 1957, August 10, 339). He said that plating the sternum was one way of dealing with this problem. The most effective method probably was immediate tracheotomy and the use of a positive pressure respirator before the condition of wet lung developed.

Synovioma of tarsus—*Mr Henry* showed a patient who had complained of a swelling of the dorsum of the foot. Microscopical examination of a biopsy specimen showed the tumour to be a synovioma.

Recurrent dislocation of patella in children—*Mr R. Merryweather* showed two children aged ten and twelve with this condition. In order to avoid premature fusion of the tibial apophysis, Mr Merryweather had not excised the insertion of the patellar tendon with a bone block when performing a tendon transfer, but had separated the tendon with a piece of periosteum and had reinserted it under an osteoperiosteal flap on the medial side of the tibia lower down, using a single stainless steel screw for fixation. The capsule had been plicated on the medial side. The operations were performed in 1956 and so far the results were satisfactory. Mr Merryweather wondered whether, with continued

growth of the tibia, the patella might be pulled down and interfere with knee function. *Mr F. Wheeldon* said that he knew of one case in which this happened and a Z-elongation of the patellar tendon was necessary. *Mr G. Blundell Jones* said that he had operated on a patient of nine with recurrent dislocation of the patella, using the Goldthwait-Hauser procedure. After this operation the patella dislocated medially in extension and laterally in flexion: this began about six months after operation. He felt that excision of the patella had a place in treatment of this condition. The meeting considered that a Goldthwait-Hauser operation was the operation of choice for recurrent dislocation of the patella, but if it failed excision of the patella nearly always brought about a successful result.

Tendon transplants for various conditions—*Mr Merryweather* showed three patients. The first was a boy of ten with an unusual congenital absence of muscles. He had a pigeon chest and absent pectoral muscles, triceps muscles and thenar eminences. A successful opponens transplant had been done using a flexor digitorum sublimis of the ring finger as motor and rerouting it around the flexor carpi-ulnaris, using the latter as a pulley.

The second patient was a man of nineteen, now a storekeeper, with considerable weakness of the right arm from poliomyelitis in infancy. The deltoid, triceps and biceps were absent and the strength of the pectoral muscles was very poor. He had only fair movement in his hand. Arthrodesis of the wrist had been performed followed by Mayer's modification of Steindler's transplant to permit active flexion of the elbow. Both operations had been successful and had improved the function of the upper extremity considerably. He was now awaiting arthrodesis of the shoulder. *Mr Norman Capener* said that when the arthrodesis of the shoulder was being performed it was important not to put the shoulder in lateral rotation. A little medial rotation would allow gravity to reinforce the weak flexor action when the arm was abducted.

The third patient was a girl of eleven with a calcaneo-cavus deformity of the left foot following poliomyelitis. The peronei, tibialis anterior and flexor hallucis longus were transplanted to the tendo calcaneus. No tenodesis was carried out. The functional result was good and the child could stand on her toes.

Subluxation of the carpus—*Mr Merryweather* showed a man of twenty with an unusual subluxation of the intercarpal joints which was noticed after an injury. A similar condition, but less marked, was present on the opposite side. Treatment was not advised.

Manipulative techniques—*Mr J. Bourdillon* gave a demonstration of his methods of manipulation of the spine without anaesthesia. He said it was possible not only to diagnose and locate a specific spinal joint lesion, which was causing pain, but also to manipulate it.

Treatment of closed head injuries with multiple injuries—*Mr Walpole Lewin* discussed the diagnosis and management of closed injuries with multiple injuries. He said that out of 1,000 cases of head injury in the Accident Service at Oxford, there had been a mortality of 32 per cent. Fifteen per cent of the deaths had been due to other injuries. The ideal treatment of the head injury and the other injuries was usually incompatible. Head injuries required quiet and observation with the patient lying flat on his side. Other injuries required morphia, the sitting up position or activity, all of which were inimical to the treatment of a head injury. It was very difficult to make a diagnosis of an acute abdomen, spinal cord lesion or a chest lesion in the presence of a head injury, and he mentioned several points which might assist in the diagnosis.

Acute abdomen: Shock was unusual in uncomplicated head injuries; therefore the cause of it should be looked for in the abdomen. The deeply unconscious patient would not complain of pain, there was no distension, and guarding was absent. However, on auscultation of the abdomen bowel sounds might be heard even after severe head injury in the absence of abdominal injury. When the state of consciousness was less deep, the abdomen might show slight signs of rigidity in abdominal injuries, to which attention must be paid.

Spinal injury: Undue flaccidity of the limbs with absent reflexes suggested paresis. Unless deep coma was present it was unusual to find absent reflexes from a head injury alone. It was possible sometimes to detect a sensory level, and sweating was lost distal to the lesion with cord damage. Priapism was rare in head injury but common when the cord was damaged. The commonest spinal cord injury occurred in the cervical region with a head injury. Subarachnoid haemorrhage caused neck stiffness but there was no tenderness; lateral flexion of the neck was free but antero-posterior movement was painful; in a neck injury, of course, all movements were painful. When the occipital bone was fractured tenderness was usually confined to the superior nuchal line. It was always necessary to take routine radiographs of the neck in head injuries.

Chest injury—Radiographs were sometimes unhelpful. A careful examination should be made and surgical emphysema looked for. Suspicion of a chest injury should always be aroused by rapid breathing or cyanosis in the presence of a clear airway. It was wise to assume that the cyanosis was due to the chest unless there was proof to the contrary.

In the management of head injuries it was important to establish a firm baseline by careful examination, paying attention to the level of consciousness, pupils, fundi and limb reflexes including plantar responses. Continued routine observation was most important, and shock charts should be maintained. These could easily be recorded by the nursing staff. Only the pattern of the chart was important and the actual level of the recordings did not matter so much. Eighty per cent of patients with head injuries improved on waiting, and therefore it was important to assess the patient first, to justify a waiting policy. Delay of up to five days in the definitive treatment of associated fractures elsewhere had not prejudiced satisfactory union. Of forty-eight fractured femurs with head injuries the end results were as satisfactory after delayed treatment as if they had been dealt with immediately.

With regard to blood transfusion in cases of head injury Mr Lewin said that of course if patients had lost blood from any cause it should be replaced. The diagnosis of blood loss, however, should not be based solely on the blood pressure. Lobar collapse of the lung would cause a fall of blood pressure and over-transfusion would make this worse. When a patient was dying from a head injury the blood pressure fell and the pulse rose.

Mr Lewin emphasised that in order to obtain best results in these difficult cases it was important that the patient should be treated in accident centres where all specialist services were available. *Mr P. S. London* said that in the Birmingham Accident Unit it had been found that some states of unconsciousness were induced by cerebral anoxia; and restlessness, simulating cerebral irritation, had been associated with severe blood loss. In such cases only transfusion would help. Tracheotomy had been found to be a most helpful procedure in cases of severe head injury as well as in injuries of the jaw. In abdominal injuries associated with head injuries auscultation of the abdomen was valuable and he considered that the absence of bowel sounds was a most important sign of intra-abdominal pathology.

The rocker principle in footwear—*Mr A. W. Fowler* said that in footwear with rigid soles some provision must be made to compensate for the lack of flexibility of the sole in the situation of the metatarso-phalangeal joints. This had been done by various means, such as the anterior heel, the hinged patten and the toe roll on a clog. In ordering a cork raise the surgeon converted a semi-flexible sole into a rigid one and an adequate toe roll should be incorporated. He illustrated the comfortable type of cork raise for general use. The cork should have the same depth beneath the heel and the ball of the foot and should roll off by one inch towards the tip of the shoe. This allowed a rocking action which was a great help to patients and enabled them to walk with a normal heel-to-ball gait. A more elegant way of raising a feminine shoe was by adding a high wooden heel and having a separate cork rocking sole. A rigid leather rocking sole was used in pain or stiffness of the metatarso-phalangeal joints and a rocking heel was described which was found useful for pain and stiffness in the ankle joint. *Mr F. C. Durbin* mentioned a simple method of determining whether the rocker on a shoe was satisfactory. The sole of the shoe or boot should be placed on a flat surface with the rocker and toe in contact with the latter. If the rockering was sufficient, the distance that the back of the heel was raised off the flat surface should be at least an inch and a half.

Apparatus for nailing the fractured femoral neck—*Mr K. H. Pridie* on behalf of Mr E. A. McVerry demonstrated a wooden operation frame which was used at Bristol for nailing the fractured neck of femur. The total cost of the apparatus was about £1, and any carpenter could make it. It was easily portable and could be used on an ordinary operation table.

The reconstruction of osteoarthritic knees by means of a cartilage graft and other methods—*Mr Pridie* showed slides demonstrating how it was possible to graft articular cartilage over eburnated areas in osteoarthritic knees. His interest had been stimulated by operating on a fractured femoral condyle ten days after the injury, when he discovered that the cancellous bone in the gap between the fragments had been covered with hyaline cartilage. This showed that cancellous bone was an excellent bed for hyaline cartilage. He had subsequently effectively grafted some hyaline cartilage on to an eburnated area on the lateral femoral condyle of an osteoarthritic knee, and then performed an osteotomy of the tibia lower down to correct co-existent genu valgum. Mr Pridie demonstrated with slides and photomicrographs how this cartilage continued to grow. At first it was fibrocartilage, but after some time it was converted into hyaline cartilage. The patients recovered a useful range of movement, but how long this state of affairs would continue it was difficult to predict. *Mr John Bastow* said that the method opened up the possibilities for salvaging a knee joint the only alternative treatment being an arthrodesis.

Osteoclastoma of long bones—*Mr Norman Capener* presented the late results in cases of osteoclastoma affecting the major weight-bearing bones, treated by him by surgery. The tumours had invaded almost the entire thickness of the involved bones and on the Continent would have been dealt with by resection. He had carefully curetted and scraped out the cavities, which he had then filled up with

autogenous cancellous bone and compact strips. The patients had been followed over ten years. Radiographs were shown demonstrating the subsequent filling in of cavities and most of the patients had shown no signs of recurrence. The extent of joint movement afterwards, which was a surprising amount, was shown on slides. His results rebutted the radical form of treatment.

SOUTH AFRICA

SOUTH AFRICAN ORTHOPAEDIC ASSOCIATION

The Annual Congress of the South African Orthopaedic Association was held in Durban from September 16–21, 1957, under the Chairmanship of Dr C. T. Moller.

Honorary Members—At the Annual General Meeting held on September 16, 1957, Sir Harry Platt and Mr F. P. Fouché were elected Honorary Members of the South African Orthopaedic Association. They were informed of this at the customary annual dinner.

Office-bearers—The following were elected office-bearers of the Association for the ensuing two years: president, A. J. Helfet (Cape Town); honorary treasurer, S. Sacks (Johannesburg); honorary secretary, G. Dommisse (Pretoria); committee members: C. T. Moller (retiring president), J. M. Edelstein (Johannesburg), G. T. du Toit (Johannesburg), J. G. du Toit (Pretoria).

Clinical Meetings

The programme extended over five days. There was a combined meeting with specialists in physical medicine at which *Dr J. Cyriax* (London) spoke on " the Painful Shoulder." There was a plenary session on " the Surgery of Repair " at which Mr W. Gissane (Birmingham) spoke on " Surgery of Injuries of the Hand " and *Sir Harry Platt* summed up the discussion.

At another plenary session on " Treatment of Pain " *Mr A. Lewer Allen* spoke on " Pain in the Unstable Fracture."

A clinical programme was presented at the Addington Hospital by the Durban members of the Association at which some interesting cases were shown.

Mr R. Hill (Durban) showed a baby with congenital pes calcaneus plus a strange congenital undifferentiated band of tissue stretching from the tendo calcaneus to the ischium in one continuous piece. *Mr C. Kaplan* (Durban) showed a girl of eighteen years who had been unsuccessfully treated for a congenital dislocation of her left hip by two shelf operations at the age of two and a half years and at four and a half years. The discussion ranged around the treatment. She had no pain but did not like wearing a raised shoe to compensate for the three inches of shortening of the left leg. Some members suggested shortening the opposite leg for cosmetic purposes only. Others advised leaving her alone. *Sir Harry Platt* advised a bifurcation osteotomy in order to postpone the onset of pain. *Mr F. Hedden* (Durban) showed an excellent result in a case in which the hamstrings had been transplanted into the patella for poliomyelitis. A supracondylar osteotomy had previously been done on the knee to correct a flexion deformity. He also showed a case of ununited fracture of the scaphoid bone, and the various methods of treatment for this condition were discussed. Some members advised further immobilisation in plaster. Others stressed the importance of reducing a fracture of the scaphoid by pulling on the thumb. *Mr Gissane* advised immobilisation of wrist and elbow to prevent rotation strains: after six weeks the plaster might be discarded. He stressed that it is bad teaching to recommend immobilisation of a scaphoid until it is radiologically united. Many people do normal work without the knowledge that they have ununited carpal scaphoids. *Mr Helfet* mentioned an operation to fuse the capitate to the scaphoid in cases of non-union.

Mr G. Bickerton (Durban) showed a boy of fifteen years who had presented with signs resembling tuberculosis of the hip with discharging sinuses and flexion contracture. This eventually proved to be a case of chronic appendix abscess and was cured by appendicectomy. No evidence of tuberculosis or actinomycosis was present.

Mr J. Raftery (Durban) showed a case of pseudarthrosis of the tibia in a boy aged eleven years in whom he had obtained successful union with a massive cortical intramedullary bone graft supplied by the bone bank.

Mr R. Hill (Durban) showed a patient with traumatic paraplegia and calcification around the hip joint. The cause of calcification in paraplegics was discussed. Thrombosis of veins, trauma and excessive physiotherapy were mentioned by *Mr L. Mirkin* (Port Elizabeth) as possible causes. *Mr Sacks* mentioned cases he had seen and concluded that the etiology was obscure and none of these theories of causation could be accepted. *Mr Helfet* mentioned that in Holland it was asserted that sodium citrate taken by mouth could prevent this calcification.

Giant-cell tumours—*Sir Harry Platt* (Manchester) recalled that this tumour is comparatively rare and should be distinguished from other cysts of bone. One of these tumours occurs each year in each large teaching hospital. The speaker had only had forty of these tumours in forty years. In the nineteenth century Paget, Nélaton and others regarded these tumours as benign. Bloodgood had introduced the term "benign giant-cell tumour"; Geschickter and Copeland (1930) reinforced the idea that it was fundamentally a benign tumour. Jaffe and Lichtenstein confirmed the view that it had an epiphysial and not a metaphysial origin. Sir Harry recognised three types: benign, progressive and malignant. The tumour occurred equally in both sexes and mostly in the long bones. In the differential diagnosis dystrophic cysts, atypical cysts and aneurysmal bone cysts should be distinguished. As regards prognosis, if these cysts were perfectly curetted, lasting cure could be obtained. Repeated curettage might lead to malignancy, and so might irradiation.

In twenty-seven cases curetted and cauterised without bone grafting, fourteen had given a lasting cure; seven subsequently required amputations and two knee joints required fusion. In twelve cases excision and bone graft replacement were required.

As regards treatment by irradiation, reports were conflicting. The speaker advocated primary surgery for accessible tumours. With irradiation too much time was involved; the adjacent joint might be damaged and there was the remote possibility of malignant change.

Mr Edelstein mentioned a case he had seen with giant-cell tumours in several bones. *Sir Harry Platt* could not recall having seen such a case. On the question of filling the curetted cavity with bone chips Sir Harry Platt stated that he did not do it unless the cavity was large and collapse of the cavity imminent.

Paraplegia in spinal tuberculosis—*Mr A. C. Boonzaier* (Johannesburg) said that tuberculous paraplegia was common in the South African Bantu; a large proportion of patients with spinal tuberculosis became paraplegic. The paraplegia was caused by extra-dural compression of the spinal cord by the products of the inflammatory process and its mechanical disturbance of the spinal canal. The dura mater was never transgressed. Cases should preferably be graded according to the severity of the neurological lesion.

Grade I—There was a clinically obvious upper motor neurone lesion but the patient could still walk; *Grade II*—The patient was unable to walk and had an upper motor neurone lesion but still had voluntary movements; *Grade III*—Complete paraplegia, no voluntary movements. When Grade I or II paraplegia was complicated by bladder involvement, contractures or bed sores or extensive sensory loss, the case was classified as Grade III.

Paraplegia of Grade I or II was treated by immediate spinal fusion and antibiotics. Paraplegia of Grade III was treated by immediate antero-lateral decompression followed by spinal fusion after a reasonable interval.

Analysis of the cases treated at Baragwanath over the last four years showed the early results of cases in Grade I and Grade II treated by spinal fusion to be very good. There must, however, be clear clinical and radiological evidence of healing and the neurological picture must improve considerably; any lack of improvement was an indication for antero-lateral decompression. If a large abscess or sequestrum was present antero-lateral debridement and replacement with bone grafting was essential. Spinal fusion was not a cure for spinal tuberculosis. It merely provided the most efficient and rapid immobilisation of the lesion. When antero-lateral decompression had been done the results varied directly with the type of compressing agent found: lesions with pus, caseous debris and sequestra give better results than fibrous tissue and a firm bony ridge. Patients treated for long periods by antibiotics did not do so well after antero-lateral compression of the fibrocartilaginous nature of the compressing agent, commonly seen in children. Despite recent opinion, there was a definite and essential place for spinal fusion in Pott's paraplegia. The most important prognostic features were the grade of lesion and the nature of the compressing agent. Antibiotics causing fibrosis, such as streptomycin, should be strongly suspect.

Mr Boonzaier presented his results in fifty cases of spinal fusion and thirty cases of antero-lateral decompression for tuberculosis: 58 per cent were completely relieved; 18 per cent were greatly improved; 6 per cent showed some improvement but still had to use calipers for walking; 12 per cent showed no improvement; 6 per cent resulted in death at some later stage.

An unusual hereditary bone dystrophy—*Mr M. Lunz* (Johannesburg) described two patients with onycho-osteo-dysplasia in whom the main presenting features consisted of epiphysial dysplasia of the knees, ankles and feet, small subluxating patellae, dislocation of the radial heads, iliac horns projecting from the pelvis on to the buttocks and absence or ridging of the nails of the fingers and toes. Mr Lunz traced the genealogical tree of a South African family through six generations from 1692 in which the condition appeared to have been present in each generation.

Slipping or displacement of the vertebral end-plates simulating disc prolapse—*Mr A. J. Helfet* (Cape Town) related the story of two young, healthy lads aged fifteen years and sixteen years. They had developed acute pain in the back with radiation down both legs, after a sudden strain at tennis in one case and after lifting a heavy bag of wheat in the other. They had flat, rigid spines with weakness of some of the leg muscles and sensory disturbance in the legs. Conservative treatment was of no avail. At operation in the first case a sequestrated intervertebral disc was found at the L.4–5 level attached to a ledge of cartilage which appeared to be attached to a posteriorly displaced vertebral end-plate. The disc was removed and the projecting end-plate was nibbled away. The patient made a complete recovery. The second patient had a slight pyrexia and could hardly move about in bed. At operation a bulge was found at the fourth lumbar space with a posteriorly projecting ridge above it. An attempt was made to grasp this projection, but it slipped forward between the vertebrae and the bulging disc disappeared with it. No attempt was therefore made to remove the disc or slipped end-plate, as they appeared to have slipped back into place. The patient was kept in bed for fourteen days after operation and all the motor and sensory disturbances disappeared. Radiographs of the spine taken five months later showed a narrowed intervertebral space with some marginal sclerosis and possibly some slight erosion. It was thought that these appearances probably indicated some mild infection. *Mr S. Sacks* mentioned that primary intervertebral disc infection sometimes occurs in children and that the oedema and vascularity of the infection might possibly lead to the pathology described by Mr Helfet. *Mr J. M. Edelstein* showed radiographs of cases with anterior subchondral protrusion of discs and wondered if these posterior protrusions described by Mr Helfet could not be described in the same light.

Congenital dislocation of the hip—*Mr D. J. Retief* (Johannesburg) emphasised the necessity for open reduction and removal of the intervening limbus if closed reduction failed. A case was also made for arthrography of the hip. At some clinics in England limbectomy was almost a routine procedure. *Mr J. M. Edelstein* stated that before he could accept that the limbus presented an insuperable difficulty to closed reduction he would like to know how the limbus was formed. *Mr C. Möller* said that when he operated and removed the obstructing material he usually found only a frail piece of tissue. Even when this was removed the head of the femur did not seem to settle deeply into the acetabulum unless the femur was placed in marked medial rotation. Only in a third of all cases was he unable to secure a satisfactory reduction by closed methods. *Sir Harry Platt* said there were many different types of congenital dislocation of the hip. It was not true that a complete dislocation first went through a stage of subluxation: subluxation was a type of its own. Arthrography was of no use and was not a great need. He had done 140 open reductions and less than 30 per cent of his cases had required this operation. In children under three closed manipulation produced a good functional and anatomical result. Derotation osteotomy was very rarely necessary in young infants: it was only done at a much later stage. The question of which hip to treat primarily by open reduction was still unanswered.

Avulsion of distal tendon of biceps—*Mr W. J. Thomas* (Johannesburg) reviewed the reported cases of biceps tendon avulsion at its insertion. By 1951 only ninety-eight cases had been reported. The lesion usually occurred in elderly men and in the dominant arm. At the site of the lesion the radius was usually smooth, without any periosteal flakes. The tendon was curled up in a snake-like fashion and often retracted high up into the arm. The treatment depended on the degree and site of rupture, the age of the patient and his type of employment. The tendon was usually sutured back to its radial insertion or into the brachialis tendon. Leaving it alone without suture also gave a good result. He described two patients whom he had recently treated. Through Henry's incision the radial tuberosity was roughened and two braided steel wires were passed through drill holes in the radius and the tendon was tied down. One patient returned to work after ten weeks with 20 degrees' limitation of supination. Other members present mentioned a total of ten similar cases that they had encountered.

Tuberculosis of the knee joint—*Mr A. C. Boonzaier* (Johannesburg) said that tuberculosis of the knee comprised 15 per cent of the cases of bone and joint tuberculosis admitted to Baragwanath Hospital. He described a classification of pathological advancement that had been evolved to assist in treatment and estimation of prognosis. *Type I*—Synovial disease only, as shown by clinical, radiological and open arthrotomy investigation; *Type II*—Synovial disease plus early damage to the cartilage and bone but not severe enough to constitute a destroyed joint; *Type III*—Frank destruction of the joint.

The advent of antibiotics had allowed one of the greatest advances in orthopaedic surgery, namely the surgical eradication of bone and joint tuberculosis. In no other joint was this more clearly demonstrated than in the knee. In cases of *Types I* and *II*, after diagnostic arthrotomy and institution of antibiotic therapy, the knee was immobilised for a month, then all splints were removed and weekly intra-articular injections of iso-nicotinic acid hydrazide (50–100 milligrams) were given. Iso-nicotinic

acid hydrazide and para-amino-salicylic acid were given systemically. Streptomycin was given only during first month. Treatment continued in hospital with no weight bearing for three to six months, until there was evidence of clinical quiescence.

In Cases of *Type III* immediate compression arthrodesis was advised. The results were better than those for any other joint, but many patients required arthrodesis because they were seen too late.

The clinical significance of the intervertebral disc—*Professor C. L. Allen* (Cape Town) said that the rôle of the muscles in controlling the stability of the spine was extremely subtle. The intervertebral disc could withstand a pressure of 30 lb. per square inch. He showed a model depicting the spinal column and its balancing forces. By means of electromyographic studies, the work done by the abdominal and sacrospinalis muscles in the erect position and during flexion and extension of the spine, was shown by graph tracings. By this method it was revealed that during active extension of the spine the abdominal muscles were contracting to prevent over-extension. The sacrospinalis muscles showed no contractions during this movement. During active flexion of the spine the sacrospinalis contracted to prevent the patient from falling forwards. When the spine was being extended from the fully flexed position, however, the sacrospinalis muscles contracted and assisted in restoring the erect position. From these graphs it appeared that the muscles played an important rôle in backache. During the acute stage of backache the primary cause, such as a slipped intervertebral disc, played the dominant rôle. In the subacute phase of backache the secondary overlay of muscle fatigue pain played a larger part in the symptomatology, and in the chronic stage of backache it played the main part.

Some examples of the anatomy of injury in the acute stage—*Mr W. Gissane* (Birmingham) showed, by means of radiographs, various types of acute injuries and discussed their immediate and remote treatment.

Intramedullary fixation of fractures—*Mr S. Sacks* (Johannesburg) considered that intramedullary fixation of fractures was useful if well done in properly selected cases by a surgeon competent in fracture treatment. A full knowledge was necessary of the indications, the advantages, the instruments and appliances necessary, the correct operative procedure and the post-operative treatment. These were fully discussed and the results in 100 patients so treated were mentioned. The stay in hospital with fractured femurs so treated was only twenty-eight days as compared with 135 days for patients treated by traction. These patients returned to work in 105 days as compared with 216 days in patients treated by traction only. The main indication in South Africa for intramedullary nailing of the femur was shortage of hospital beds and inadequately trained staff to nurse patients satisfactorily in traction. Complications were uncommon if strict asepsis was observed. The nail need not be removed from the femur if it was not causing any trouble. After operation an anterior slab of plaster was applied to the leg with the knee in 90 degrees flexion. It was removed after twelve days, when the stitches were removed. The patient therefore immediately had an adequate range of flexion because the quadriceps had not become adherent with the knee in extension. The patients were allowed out of bed with crutches on the fourteenth day and allowed to take weight on the affected leg at six weeks. Intramedullary nailing of the tibia was not advocated. In fractures of the humerus the nail should be introduced from below through an oblique drill hole in the lateral supracondylar ridge. It should never be allowed to pass through the greater tuberosity. The blind method of nailing should never be employed.

Traumatic dislocation of the knee: a review of six cases—*Mr I. Southgate* (Johannesburg) said that the knee was affected in only 2·3 per cent of dislocations of major joints. The different types and mechanisms of dislocation were described. Six cases were analysed in detail, and the diagnosis, with special regard to dislocations requiring open reduction and in which vascular injury had occurred, was discussed.

Mr W. Gissane mentioned that when the dislocation had been reduced the stability of the ligaments must be tested. If they were unstable an operation to repair them must be done immediately. Traction injuries to nerves and vessels did not lend themselves to surgery. Conservative treatment did not jeopardise the coliateral circulation. *Mr J. G. du Toit* mentioned that arterial grafting in limbs was not very successful. He also believed that repair of ligaments was necessary to improve stability.

Treatment of poliomyelitis in the early stages—*Mr C. Kaplan* (Durban) recounted the complications that might occur in the early stages of poliomyelitis, and discussed the treatment of bulbar lesions, with laryngeal and deglutition paralysis, and of respiratory paralysis.

Slides were shown of the various respiratory instruments and aids employed. Mention was made of the method used to teach patients to perform glosso-pharyngeal breathing to enable them to leave their respirators. Pictures were shown of the cervical braces or " halos " used when the spine had been fused to prevent the head from falling forwards. Orthopaedic surgeons should have direct access to patients with poliomyelitis from the commencement of the illness.

NEW ZEALAND

NEW ZEALAND ORTHOPAEDIC ASSOCIATION

The Seventh Annual Meeting of the New Zealand Orthopaedic Association was held in Auckland on October 16–18, 1957. The President, Mr H. Walden Fitzgerald, was in the chair.

Judet replacement operations—*Mr Allan Macdonald* (Auckland) had reviewed the results of one hundred cases of prosthetic replacement of the femoral head for subcapital fractures of the femoral neck. A postero-lateral approach was used, and after operation a single below-knee padded plaster was applied, with a wooden cross-bar to keep the foot inverted. Patients selected for this operation were over sixty-five years of age except those who had already undergone unsuccessful nailing. Twenty-eight patients died in hospital. The comfort of the patients, the ease of nursing and the short stay in hospital commended the operation for the elderly patient with a subcapital fracture. *Mr W. Parke* (Gisborne) pointed out that the immediate hospital mortality was higher than in a series of cases treated by nailing which he had reviewed in 1947.

Internal fixation in displacement osteotomy of the upper end of the femur—*Mr C. Milsom* (Tauranga) had reviewed twelve patients treated for painful osteoarthritis. He aimed at division of the bone at McMurray's level with correction of deformity and, after trying various methods of internal fixation, had found the Bosworth spline the most satisfactory. He was impressed by the early relief of pain and the lack of complications. *Mr Alexander Gillies* (Wellington) favoured this type of operation for osteoarthritis of the hip, and *Mr Bruce Hay* (Hamilton) considered it suitable also for some fractures of the femoral neck.

Neuritis of the deep branch of the ulnar nerve *Mr Rex Blunden* (Christchurch) described two patients with neuritis of the deep branch of this nerve caused by pressure of ganglions in the palm. A woman of fifty-three years complained of pain in the hand for several months. There was paralysis of the ulnar intrinsic muscles of the hand without sensory loss. At operation the nerve was found to be stretched over a large ganglion. Motor power returned in eight months. The second patient was a man of thirty-nine who had received a minor injury to the hand a few weeks before. Again there was loss of ulnar motor power in the hand without sensory loss. At operation a large ganglion was found medial and distal to the hook of the hamate bone with the nerve stretched over it. In four months motor recovery was nearly complete.

Subscapularis transplant for recurrent dislocation of the shoulder—*Mr Alan Alldred* (Dunedin) had reviewed ten cases observed for one to five years. De Palma's modification of the procedure described by Magnusen and Stack had been used, in which the subscapularis tendon was transferred to a lower and more lateral insertion in the humerus. The limb was fixed after operation with a Velpeau-type bandage for three weeks, after which the shoulder was exercised. There had been no recurrence. In some cases there was no limitation of lateral rotation of the shoulder after operation. This accorded with the original conception that the main obstacle to redislocation was a muscle sling counteracting the downward pull of the pectoralis major and latissimus dorsi muscles in the position favourable to dislocation. The method seemed a useful alternative to the Putti-Platt operation. *Mr A. B. McKenzie* (Christchurch) doubted whether the method would be satisfactory when there was ballooning of the capsule. *Mr Alldred* replied that the capsule was always ballooned.

Multiple angiomatosis—*Mr P. Grayson* (Palmerston North) described a child of four years with multiple lesions of bone. Radiographs showed the bones gradually disappearing as they were involved. A biopsy had revealed multiple angiomatosis.

The gracilis transfer for recurring dislocation of the patella—*Mr H. K. Christie* (Wanganui) described an operation in which the gracilis tendon was detached at its lower end, passed through a subperiosteal groove in the patella and sutured to itself. The synergistic medial pull of the adductor gracilis acted when the quadriceps contracted, maintaining the patella in position.

Supracondylar fractures of the humerus—*Dr W. Fraser* (Auckland), introduced by Mr O. R. Nicholson, had reviewed 308 patients treated at Middlemore Hospital. Seventy-eight per cent were under twelve years old with the highest incidence at six years. Closed reduction was successful in 70 per cent of cases. Further manipulation was required in 26 per cent, and in thirteen cases open operation was performed when closed reduction had failed. Ten patients had primary operative treatment because of existing complications. Five patients had vascular complications. Of four patients with brachial artery spasm, two were relieved by isolating the vessel and two required excision of a segment of the artery. Seventeen patients had nerve palsies: ulnar, two; median, twelve; radial, seven. Follow-up studies showed that good results can be expected from closed manipulation at all ages. Open operation

in the uncomplicated case gave inferior results. Vascular complications were the main indication for operation. Nerve lesions did not benefit from early operation and were better dealt with after the fracture has united.

Mr H. K. Christie (Wanganui) advocated skeletal traction for this injury. *Mr W. Parke* (Gisborne) was not altogether satisfied that the standard methods of treatment were adequate to control varus or valgus deformity. *Mr O. R. Nicholson* (Auckland) pointed out that this was one of the largest series of cases he had seen, and that the results showed conclusively that conservative treatment was superior to operative treatment.

Stabilisation of the foot—*Mr Bruce Hay* (Hamilton) had reviewed eighteen cases of stabilisation operations of different types for a variety of conditions with a follow-up period of seven to twenty-one years and an average of twelve years since operation. The results were reassuring. Nine patients had no disability, and of these five were doing heavy work. Eight patients had symptoms; of these, one patient had to change his job; the remainder had regarded the symptoms as not severe enough to demand further treatment. A Maori boy operated on for talipes at the age of six presented the only complete failure. *Mr C. Milsom* (Tauranga) said that he had been satisfied with his results, but found the valgus foot difficult to fuse satisfactorily.

Problems in the use of metal inserts—*Dr H. J. A. Colvin* (Auckland), by invitation, said that it was important that each hospital should investigate its stocks of plates, screws and similar instruments. All material that was magnetic and did not contain manganese should be discarded as unsafe. He described simple methods of testing each piece which would eliminate all that was unsafe. He pointed out that it was difficult to obtain from manufacturers of metal inserts details of their exact composition.

Pain in the arm—*Dr G. Glasgow* (Auckland), by invitation, recalled the importance of determining the site of the lesion before deciding its nature. Pain was localised by the muscles supplied by a nerve root and not by the dermatome. Pain arising in a nerve root often gave tingling in specific fingers. Pain of nerve root origin lasting for longer than six weeks was suspicious and the case should be reviewed with a lumbar puncture if necessary. Lesions of peripheral nerves were generally not accompanied by persistent pain. Median nerve compression in the carpal tunnel was an exception. He stressed that this condition was often transient during pregnancy or the puerperium. Lesions of the brachial plexus were more easily recognised by the anatomical distribution of the symptoms and signs. Neuralgic amyotrophy and pain arising in the thalamus were more difficult to recognise.

During the meeting *Mr R. H. Dawson* (Palmerston North) showed a film of Robert Jones at work, which he presented to the Association. *Mr O. R. Nicholson* described his tour as a British Orthopaedic Association travelling fellow and showed a film made at the Royal National Orthopaedic Hospital and the Institute of Orthopaedics with the consent of Mr H. J. Seddon on abnormalities of the gait. *Mr Alldred* said that this film would be excellent for teaching purposes.

Mr H. Walden Fitzgerald in his presidential address reviewed the history of amputations.

AUSTRALIA

AUSTRALIAN ORTHOPAEDIC ASSOCIATION

The Annual General Meeting was held in Adelaide, South Australia, from August 15 to 19, 1957.

Presidential address—*Mr A. Hamilton* (Sydney) read a paper entitled " Hugh Owen Thomas: The principles of treatment of diseased joints and fractures," indicating from quotations the soundness of Thomas's basic principles.

Some apparently little-recognised features of internal derangements of the knee—*Mr B. T. Keon-Cohen* (Melbourne) commented on five notable and common conditions affecting the internal mechanism of the knee. Peripheral detachment of the semilunar cartilage was not uncommon and could cause the same symptoms as a torn cartilage, but a peripheral attachment could heal without the inevitable necessity for operation or recurrent trouble. Often in osteochondritis dissecans, despite radiological demonstration of a separating fragment, when the knee was opened little evidence of the lesion could be found; this made him more conservative. He considered that a painful coronary ligament was not always traumatic but the pain was persistent and troublesome around the line of attachment of the semilunar cartilage and was often relieved only by removal of the cartilage. The painful infra-patellar fat pad caused most characteristically tenderness on pressure over the patellar tendon, and the patellar fat pad often bulged to either side of this. The condition could be most intractable, and on several occasions it had been necessary to remove the fat pad. Usually, however, it resolved after prolonged rest and physiotherapy. In a few cases he had obtained relief by infiltration with hydrocortisone. Lesions of the anterior cruciate ligament were often confused with injuries of the

medial semilunar cartilage, and explained at least some of the poor results from its removal. It was important to inspect the anterior cruciate liagment when the inner side of the joint was opened. Quite obvious lesions ranging from a recent small haematoma or minor fraying of the anterior part or complete detachment of part of the ligament from the tibial spine were seen remarkably often, and seemingly could not be diagnosed before operation, because symptoms and signs often strongly indicated a medial cartilage lesion, even with symptoms of locking.

Fractures about the knee—*Mr M. Maxwell* (Sydney) discussed fractures involving the knee joint. Among various treatments for patellar fracture, he quoted several cases to emphasise the excellent results that could follow excision of the patella. In compound fractures he thought this much wiser than internal fixation. The results of treatment of fractures of the tibial condyles were not nearly so good as those of the patella. Typical injury was by direct lateral pressure on the inner or outer side of the knee, often by a car bumper. Various treatments were discussed, including closed reduction and immobilisation in plaster, continuous traction by skeletal traction through the tibial tuberosity, immediate movement in Hamilton Russell traction, and open reduction and fixation of the fragments by screw or bolt. In fractures of the femoral condyle crushing injury was relatively rare and the weight-bearing articular surface was often severely damaged. If one condyle only had been split off, closed reduction might be possible; if both condyles have been fractured, open reduction and fixation with screws or transverse bolts was usually indicated. In T-shaped fractures the supracondylar fracture could be dealt with at the same time as the femoral condyles.

Degeneration of the knee joint—*Mr R. Robinson* (Sydney) spoke of recent theories and modern thought on the causation of rheumatoid arthritis and osteoarthritis and also treatments from the medical and physical points of view and the role of hydrocortisone, cortisone, ACTH and Butazolidin in the treatment of these types of arthritis.

Mr A. Dwyer (Sydney) said that one form of injury of the knee which should be recognised was the tear of the lateral ligament as well as the biceps tendon. This injury called for early operation because the biceps tendon retracted and operation was very difficult if undertaken more than two weeks after injury. *Mr H. Barry* (Sydney) recalled that the common condition of chondromalacia patellae was often confused with a medial cartilage lesion. In transverse fractures of the patella he preferred a screw to encircling wire and doubted whether excision of the patella was so universally successful as the speaker had suggested. He believed that depression of the tibial plateau from fracture always recurred after reduction. *Mr A. Watts* (Sydney) agreed that peripheral detachments of the cartilage could heal, despite earlier teachings. *Mr N. Morgan* (Sydney) described traction injury of the lower pole of the patella. He was dissatisfied with the treatment of tears in medial ligaments of the knee, either operative or non-operative. He had used a tendon transplant but this also had not been very successful. *Mr W. Stening* (Sydney) doubted whether full strength ever returned to the quadriceps after excision of the patella. In tibial condylar fractures he thought that open reduction was often necessary to dig the torn cartilage out of the cleft in the bone before reduction could be achieved. *Mr A. McSweeney* (Brisbane) described traumatic detachment of the posterior part of the tibial surface with an associated cartilage injury. *Mr G. Kerridge* (Newcastle) asked Mr Keon-Cohen if he thought the only reason for operation in osteochondritis dissecans was complete separation of the fragment. He asked him what he meant by conservative treatment. *Mr A. Hamilton* (Sydney), in agreement with *Mr Keon-Cohen* and *Mr Teece*, favoured a back splint after excision of a semilunar cartilage. In the treatment of tibial plateau fractures he preferred a Thomas's splint to plaster. *Mr D. Parker* (Hobart) said that he sometimes removed the cartilage immediately after injury, especially for economic reasons if the knee were locked. He inquired whether hyperthermia still had a place in the treatment of arthritis. *Mr P. Williams* (Melbourne) discussed internal derangements of the knee in children. He mentioned two cases of hypermobile medial semilunar cartilage in children, aged eleven and eight, cured by removal of the cartilage. *Mr J. Jens* (Melbourne) thought that chondromalacia patellae was a frequent complication of cartilage operations from too heavy retraction of the patella. He had used rib graft from the bone bank to build up under fractures of the lateral condyles. *Mr G. McKellar* (Sydney) said that the back of the patellar should always be inspected when the knee was open. *Mr J. Colquhoun* (Melbourne) described a case in a child of multiple lesions of osteochondritis dissecans in both elbows, both knees and both calcanei. The sclerotics were blue. He removed the loose bodies from the elbows and then kept the child at rest and the other lesions healed. He disliked a back splint after excision of a cartilage.

In reply, *Mr Keon-Cohen* stated that he had not found chondromalacia patellae common. He advocated conservative management of ruptured medial ligament, rather than early operation. He had not operated upon children under the age of fourteen in whom he thought the cartilage might be hypermobile but afterwards would tighten and did not require removal. *Mr Maxwell* said that he preferred early movement in compression fracture of the tibial plateau.

The unstable subtalar joint—*Mr A. Dawkins* (Perth) described injuries to the lateral ligament of the ankle. He reminded the audience of the anatomy of the lateral ligament, pointing out that it was made up of three bands, the anterior and posterior portions of which stretch between the lower end of the fibula and the talus, and the middle band—the calcaneo-fibular ligament—stretches between the tip of the fibula and the calcaneum. In injuries it might be ruptured and give rise to instability. Rupture of the anterior component was well known and had been well described by Watson-Jones who had described an operation for its repair. Mr Dawkins described several cases in which he had replaced the ruptured ligament by threading the peroneus brevis tendon through a hole in the fibula and into a hole on the outer side of the calcaneum. He described another case in which recurrent locking was shown at operation to be due to occasional slipping of the peroneus brevis tendon between the opened up subtalar joint surfaces. The operation described gave a satisfactory result in this case. This series of four cases led him to believe that rupture of the calcaneo-fibular ligament was probably commoner than was appreciated. Radiographically, there was little or no tilting of the talus at the ankle on forced inversion, although clinically there appeared to be an increased range of forced inversion. Consequently he believed that the instability occurred in the subtalar joint and was commoner than had been supposed. He described experiments on the cadaver showing that division of the calcaneo-fibular ligament caused instability of the subtalar joint; it was not until the anterior talo-fibular ligament was divided that the obvious tilting of the talus occurred. The syndrome was often associated with only mild disability. Two patients remained on full duty in the Army, the younger playing football; another remained a member of a fire brigade; and a fourth did pick and shovel work on the roads; but all suffered discomfort at times. There was a proneness to go over, discomfort on carrying weights, a strange locking in one case, and in every case a good deal of aching and swelling after vigorous use. So far the operation of employing the peroneus brevis tendon had proved quite satisfactory. *Mr J. Cloke* (Melbourne) thought the condition insufficiently recognised. He stressed the importance of radiographs in forcible inversion: clinical signs were often reliable alone without radiographic confirmation. He commented on the large number of young women sufferers. *Mr A. Watts* (Sydney) described the case of a boy of eleven with hypermobile ankle joints; there was a talar tilt of 30 degrees on inversion. He had no symptoms and was able to play games. He asked: would one operate in such a case? *Mr A. Hamilton* (Sydney) asked for location of points of tenderness and whether the operation was modified if the anterior fasciculus of the lateral ligament was torn as well. *Mr L. Bonnin* (Adelaide) and *Mr J. Colquhoun* (Melbourne) described several cases of lax lateral ligaments after injury. Mr J. Colquhoun suggested a device to hold the foot inverted during radiography. *Mr J. Gunning* (Adelaide) described cases with a chronic tenderness in the front of the lateral malleolus. He had relieved several by injection with procaine or hydrocortisone acetate. In two he had removed a synovial fringe from the outer part of the ankle joint. *Mr B. Keon-Cohen* (Melbourne) and *Mr A. McSweeney* (Brisbane) described cases in their experience. Mr McSweeney mentioned a case in which Watson-Jones's operation had failed, and asked what was to be done now. *Mr H. Hill* (Perth) thought that the symptoms in young women wearing high heels were commoner because inversion was easier when the foot was in plantarflexion.

Intra-articular therapy for osteoarthritis—*Mr R. Hodgkinson* discussed the use of cortisone preparations, and in particular hydrocortisone, in intra-articular and bursal injections. He had little doubt that non-specific inflammatory changes in joints or in bursae, tendon sheaths or ligamentous tissue were acted upon directly by this preparation, that there was subsidence of the acute pathological changes with prevention of fibrosis and adhesion formation, and that there was appreciable effect even when the changes were very chronic. The most favourable conditions were subacromial bursitis and lateral epicondylitis. In either he obtained about 50 per cent of successful results with one or perhaps two injections. He had injected Lipiodol into about twelve joints without ill effect and with minor or major relief in all. *Mr A. Dwyer* (Sydney) described a case of aseptic suppurative arthritis after the injection of hydrocortisone acetate—a second injection six months after the first. An allergic response was postulated. *Mr B. Keon-Cohen* (Melbourne) thought that de Quervain's disease could not be cured by injection. He thought also that it was almost impossible to inject an undistended hip joint. He ascribed the pain in calcinosis to tension; simply inserting a needle would sometimes bring relief. *Mr R. Robinson* (Sydney) recalled that hydrocortisone was an anti-inflammatory agent. Other measures were necessary. Perhaps procaine was the real cause of relief. Lipiodol injections into joints were used in France. It was found that oil always became loculated. Allergy to hydrocortisone injections was well known. *Mr J. Colquhoun* (Melbourne) thought it difficult to assess intra-articular injections. Normal saline, lactic acid and other agents had all been used successfully but not in a long series of cases. *Mr A. Hamilton* (Sydney) thought that injection of hydrocortisone was sometimes of value in de Quervain's disease and trigger fingers. *Mr N. Morgan* (Sydney) thought the best use of hydrocortisone was in the injection of tennis elbow.

Replacement of bone gaps by frozen bank bone—*Mr D. Parker* (Hobart) described two patients in whom a cavity was filled with frozen bone and healing followed—a child with a tuberculous cavity in the neck of the femur and a man of forty-two with a lower tibial chondroma, which was excised, the cavity being filled with frozen bone and the ankle fused. In reply to *Mr F. Callow* (Sydney) he said that tuberculosis had not been proved in the first case (no pathological examination had been carried out), and that in the second case he thought that recurrence was very likely. In reply to *Mr Keon-Cohen* (Melbourne), who asked why he used bank bone, Mr Parker said that the cavities were so large that it would be difficult to use the patients' own bone.

Conservative treatment of tuberculous cavities—*Mr J. Colquhoun* (Melbourne) described several cases of tuberculous cavities in the upper end of the femur treated conservatively, with full cure. *Mr A. Hamilton* (Sydney) described the case of a white girl aged seven from Fiji, who had a history of limping for five weeks and pain for three weeks. On the day of her examination her temperature was 99 degrees Fahrenheit and her blood sedimentation rate was slightly raised. The Mantoux reaction was negative. The radiographs revealed a juxta-epiphysial cavitating type of lesion at the upper end of the femur. The child was treated by rest and antibiotics; three months later the Mantoux reaction was positive. There was gradual improvement over the next six months. *Mr H. Barry* (Sydney) stated that during his recent visit to China he was impressed by the results of immediate excision of such lesions. *Mr J. Colquhoun* (Melbourne) found no fault with waiting and treating conservatively. *Mr A. Dawkins* (Perth) thought it was impossible that one could have a tuberculous lesion of that size with a negative Mantoux reaction. He wondered whether the Mantoux subsequently became positive because the child came to Australia and went into hospital. *Mr L. Bonnin* (Adelaide) said that it was possible to get a tuberculous lesion with a negative Mantoux reaction. *Mr M. Maxwell* (Sydney) had frequently seen in the Children's Hospital cases with initial negative Mantoux reaction later becoming positive. *Mr J. Colquhoun* (Melbourne) had had much trouble with Mantoux testing and did not regard the reaction as negative unless the same material has been used on a known reactor. *Mr C. Conacher* (Wollongong) had had a patient with a tuberculous spine with a negative Mantoux reaction for seven months which later became positive. The Mantoux testing material was considered satisfactory. *Mr A. Dwyer* (Sydney) advised conservative treatment because the epiphysial line was so close that it would probably be damaged by operation.

Fusion of neuropathic joints—*Mr C. McKellar* (Sydney) showed a neuropathic knee in a woman of forty with tabes dorsalis and interesting radiographic changes. *Mr E. West* (Adelaide) thought arthrodesis in neuropathic joints uncertain. *Mr H. Barry* (Sydney) remembered only one good result from arthrodesis in this condition. *Mr A. Watts* (Sydney) described two cases of sound fusion by arthrodesis. *Mr W. Gayton* (Melbourne) had been successful in two out of three attempts to fuse neuropathic joints. *Mr D. Parker* (Hobart) had succeeded in one of two cases. *Mr B. Keon-Cohen* (Melbourne) asked why a Charcot's knee should be fused. *Mr E. West* (Adelaide) described the operation of extra-articular fusion of Charcot's hip in which good fusion was obtained. Later the graft absorbed and destruction progressed.

Spondylolisthesis—*Mr W. Gayton* (Melbourne) showed a case of spondylolisthesis of the second cervical vertebra. *Mr E. West* (Adelaide) thought it congenital. *Mr P. Williams* (Melbourne) had had three cases of traumatic spondylolisthesis in the neck in the last two years—all treated with a bone graft. *Mr B. Keon-Cohen* (Melbourne) described a case of lumbo-sacral spondylolisthesis treated with a lumbo-sacral bone graft. This fused and then formed a pseudarthrosis. Later there was more pain in the back. A radiograph revealed fusion of the pseudarthrosis, but now spondylolisthesis of the fourth lumbar vertebra on the fifth. *Mr A. Dwyer* (Sydney) described a young man who fell from a tram, and fractured lumbar transverse processes, and had a spondylolisthesis which was regarded as congenital and was treated conservatively. In three months time the spondylolisthesis had increased considerably. Three months later again spontaneous fusion had occurred.

Comminuted fracture—*Mr E. West* (Adelaide) described an open (compound) fracture at the wrist with complete dorsal displacement of the hand and wrist, in which the median nerve and ulnar nerve and flexor tendons were displaced between the radius and ulna. After open reduction the man had made full recovery of the nerve and tendon lesions. He was fit for light work ten weeks after the injury, and later resumed most of his former work. Another case presented complete shattering of the shoulder with a band saw, which had cut vertically into the upper part of the humerus and acromion, completely shattering the upper end of the humerus. Operation included reconstruction of the humeral head, reattachment of the acromion and suturing of the deltoid and supraspinatus and infraspinatus. The man regained 30 per cent of shoulder movement and function. *Mr F. Callow* (Sydney) described an almost identical case; the shoulder was badly shattered, and was reconstituted by open reduction, with a reasonable result. *Mr W. Gayton* (Melbourne) showed two cases illustrating

considerable comminution of tibia and fibula with bone loss. In one case he accepted two inches of shortening and grafted the lower part of the fibula to the upper tibial fragment. The man was now back at heavy work with a built-up shoe. In the other case the middle third of the fibula was used as an intramedullary graft. It united to the lower fragment but not to the upper, and union was eventually secured by cancellous chips. He suggested that in some cases it was wiser to accept bone loss and shortening rather than try to fill in a gap with extensive bone-grafting procedures.

Unusual approaches for tibial grafting—*Mr R. White* (Adelaide) showed three cases illustrating bone grafting of the tibia by postero-lateral approach. *Mr E. West* (Adelaide) emphasised that this technique was indicated only when extensive scarring or infected sinus in the front of the leg precluded the ordinary approach. *Mr H. Barry* (Sydney) described two cases he had seen in which this approach had been used, but he preferred in most cases to collaborate with the plastic surgeon, getting good skin cover with the cross-leg flap or pedicle flap, which in turn would improve the circulation of the bone, before grafting bone. He considered that in some of the cases shown early amputation would have been preferable. *Mr B. Keon-Cohen* (Melbourne) agreed. He sometimes used the postero-medial approach. *Mr N. Wilson* (Adelaide) mentioned that medial to the tendo calcaneus an extensive exposure of the lower half of the tibia could be obtained by shifting the flexor hallucis longus medially. *Mr M. Maxwell* (Sydney) said that often one had to persist because amputation was declined. *Mr W. Gayton* (Melbourne) preferred a deliberate shortening of the leg to allow good skin closure in severe compound wounds. *Mr White*, in reply, mentioned that in the cases shown local factors precluded skin grafting. He thought the approach was better from the opposite side of the limb.

Excision of the talus—*Mr N. Gunning* (Adelaide) showed the case of a man on whom he had performed a Whitman's excision of the talus twenty years before and who now had no symptoms and excellent function. *Mr N. Wilson* (Adelaide) had lost one talus and had crushed the other. He now preferred the foot in which the talus had been crushed to the one from which it had been removed. *Mr J. Colquhoun* (Melbourne) recalled some excellent results from excision of the talus shown by the late A. Meehan (Brisbane) some years ago.

Calcaneo-navicular bar—*Mr L. Bonnin* (Adelaide) showed three cases illustrating calcaneo-navicular bar in the foot. The first was in a boy aged fourteen, who was first seen when aged eleven and a half. Serial radiographs illustrated the gradual development of the bar, which later fused completely. The foot was now symptomless. The second case was in a girl aged thirteen who had been treated in plaster-of-Paris for three months. A full bar between the two bones developed in six months. The child now had no pain and almost full movement. The third case was in a boy aged fifteen, first seen three years ago with bilateral spastic flat foot. He had a general anaesthetic; the feet were manipulated and put into plaster for six weeks; he then had a below-knee iron and T-strap. Firm calcaneo-navicular bars developed in both feet. In the left foot there was no inversion but in the right foot there was full inversion; there were no symptoms. These cases showed that the bar developed over a period and did not prevent inversion-eversion movements of the foot. *Mr A. Hamilton* (Sydney) said that usually in his cases the foot had been nearly fixed in eversion. In one case he had removed the bar and interposed fat pad; the child lost his pain and about six months later returned to have the operation on the other foot, which also was successful. *Mr B. Keon-Cohen* (Melbourne) described one case in which he had removed the pseudarthrosis with complete relief. *Mr N. Gunning* (Adelaide) described a case of spastic flat foot which later manifested tuberculosis of the mid-tarsal joints. *Mr N. Morgan* (Sydney) had never seen a calcaneo-navicular pseudarthrosis progress to a bar. *Mr A. Dwyer* (Sydney) did not consider that removal of the calcaneo-navicular bar should be condemned.

Malignant growths of tendo calcaneus: injury and neoplasia—*Mr W. Stening* (Sydney) described three cases of malignant disease of the calcaneal tendon seen within the last two years. In two there was undoubted injury from six to eight months before. The first case was in a man of thirty-two with a synovioma of the tendon. This, with two-thirds of the calf muscles, was removed *in toto* and deep x-ray treatment was subsequently given. However, within twelve months secondary growths had occurred in the heel and other parts of the body and the man died in eighteen months.

The other two cases were of fibrosarcoma. The same operation was performed. Both patients were still well without sign of recurrence so far. *Mr E. West* (Adelaide) considered that injury was sometimes important in initiating tumour growth and raised the question of compensation. *Mr A. Watts* (Sydney) also spoke on the relation of injury to tumour formation and described a case of leiomyosarcoma of the forearm which was accepted by the insurance company as attributable to injury. *Mr D. Parker* (Hobart) thought that in some cases injury was important in the onset of malignant tumours of bone. *Mr A. Miller* (Hobart) described two cases of synovioma, in each of which the limb was amputated, but the patient died. *Mr N. Morgan* (Sydney) described a case of a simple bone

cyst of the humerus with spontaneous fracture, which later manifested osteolytic malignant sarcoma. *Mr B. Keon-Cohen* (Melbourne) and *Mr H. Hill* (Perth) did not agree that injury played any part in tumour growth.

Plasmacytoma—*Mr E. West* (Adelaide) described an iliac plasmacytoma, in a woman of thirty-eight, benefited by irradiation. *Mr W. Stening* (Sydney) described a plasmacytoma in the ischial ramus with a pathological fracture and six weeks later dissemination throughout the skeleton. *Mr D. Parker* (Hobart) described a case of isolated plasmacytoma in a vertebra with paraplegia. With local decompression and later x-ray therapy recovery had occurred, with no dissemination in three years. *Mr B. Keon-Cohen* (Melbourne) described a similar case in which the patient was well and there was no dissemination after eight years. *Mr N. Wilson* (Adelaide) described a large ischial plasmacytoma extending into the acetabulum, and also a plasmacytoma which in 1955 caused a pathological fracture of a femur that had been plated in 1916; the lesion was curetted and filled with cancellous bone and irradiated. Two years later there was good union and there has been no recurrence. *Mr A. Dwyer* (Sydney) wondered whether it could have been a reticulosarcoma, which could be cured by radiotherapy.

Fibrosarcoma involving bone—*Mr N. Wilson* (Adelaide) showed three cases of fibrosarcoma. The first, in a woman aged sixty-five, was of the fifth metatarsal bone and was treated by local excision with the bone; four and a half years later the patient remained well. The second, in a man of thirty, was of the shaft of the third metacarpal bone. This was removed after radiotherapy. The third case, in a woman of forty-three, was of the mid-tibia and presented a less differentiated type of fibrosarcoma. The leg was amputated. *Mr G. Kerridge* (Newcastle) did not think that the diagnosis of fibrosarcoma was always correct, or that the degree of malignancy could be determined by cell type.

Paget's sarcoma—*Mr B. Keon-Cohen* (Melbourne) described the case of a man aged seventy with a soft, very rapidly growing tumour in the centre of the leg in the middle third. The tibia was grossly affected by Paget's disease. Amputation was done and the pathological report was of a benign giant-cell tumour of grade 1 growing in a tibia extensively affected by Paget's disease. *Mr H. Barry* (Sydney) thought that malignant change was rare in Paget's disease and recalled that it was often polycentric. *Mr A. Dawkins* (Perth) agreed that malignant change in Paget's disease was very rare; he had seen only one case in Perth since 1945. *Mr A. Watts* (Sydney) said that in the last five years he had seen two cases of Paget's disease in which malignant development was suspected, but only one of these was proved. He thought that injury to the bone affected by Paget's disease could simulate malignant change. *Mr J. Cloke* (Melbourne) mentioned the danger of microscopic diagnosis of tumours, which could often mislead. *Mr C. McKellar* (Sydney) mentioned one case of malignant change in Paget's disease in his own experience.

Prosthetic replacement of the femoral head—*Mr A. Dawkins* (Perth) presented a case of acrylic replacement of the femoral head for osteoarthritis, which had failed. He now wondered what to do. *Mr F. Callow* (Sydney) considered that the acrylic head should be removed, and that patients usually did quite well in spite of the consequent instability. *Mr W. Gayton* (Melbourne) had calculated seventeen ways in which the operation for acrylic head prosthesis could go wrong. He thought that generally the Austin Moore procedure was satisfactory. *Mr A. Dwyer* (Melbourne) agreed. *Mr W. Stening* (Sydney) thought that the Austin Moore prosthesis was suitable for young people and the Batchelor procedure for old. He also said that not all acrylic head prostheses failed; there were many successful cases. *Mr B. Keon-Cohen* (Melbourne) thought that all bilateral arthroplasty always failed.

The joint space at the hip after osteotomy—*Mr A. McSweeney* (Brisbane) described a man, aged sixty-five, with an osteoarthritic hip. Radiography showed an almost completely obliterated joint space. Displacement osteotomy was done with spline fixation. Two years later 90 degrees of hip flexion had been recovered and the radiograph showed some restoration of joint space. *Mr A. Dawkins* (Perth) said he had never seen joint space reappear after an osteotomy for the hip. *Mr W. Betts* (Adelaide) had seen demonstrated at Liverpool three cases presenting an increased joint space after osteotomy.

Femoral osteotomy in children—*Mr W. Betts* (Adelaide) showed a case illustrating bilateral idiopathic coxa vara from growth anomaly in the femoral neck. Subtrochanteric osteotomy had recently been done, with an interval of one month between the two sides. A second case was in a girl with poliomyelitis treated in a frame for twelve months who developed a subluxating right hip, a radiograph showing coxa valga with dislocation. A varus osteotomy was done, a Steinmann pin holding position.

Scoliosis—*Mr E. West* (Adelaide) showed three patients with idiopathic scoliosis on which he had operated during the last three years. In a girl of thirteen a curve of 90 degrees had been corrected to 55 degrees, operation being performed through the Risser jacket; in a girl of thirteen—operation two years ago—the original curve of 75 degrees was corrected to 47 degrees, but now, two years later, had relapsed to 65 degrees; a girl aged twelve, whose original angle of 70 degrees was corrected to 30

degrees; she was still in a Risser jacket. *Mr P. Williams* (Melbourne) had operated mostly on paralytic types of scoliosis, using either slivers of cortical bone from the tibia, or alternatively bank bone, especially ribs, chopped up into matchstick size. He thought that all patients lost some correction, usually from 15 to 20 degrees. *Mr F. Callow* (Sydney) favoured compact bone in slivers about ten inches long. He had removed a hemivertebra without benefit. He had also combined with the thoracic surgeon in removing the chest protuberance, but had abandoned this because it reduced the vital capacity. He deprecated operation for scoliosis under the age of ten.

Arteriovenous anomalies—*Mr N. Gunning* (Adelaide) showed a case of a child aged five with a medial swelling of the right knee. At operation he had been confronted with an appearance like a bunch of grapes hanging in the infrapatellar fat pad, which was dissected out. The swelling recurred two years later, and a partial synovectomy was carried out, revealing arthritic degenerative changes. The case was one of an arteriovenous anomaly affecting the femur and the joint, which he illustrated with venographs and arteriographs.

He showed also the case of a boy aged seven with a swelling below the knee. The arteriograph was normal, but the venograph showed a gross anomaly of the upper calf, probably an arteriovenous fistula. The popliteal vein was excised, but it was too early to estimate the result. *Mr J. Jens* (Melbourne) mentioned the danger of using a flat Smillie type knife at the back of a knee, where he had seen recently a consequent arteriovenous fistula.

Torn medial semilunar cartilage [meniscus] in a girl of ten years—*Mr A. Watts* (Sydney) described a girl aged ten whose general practitioner diagnosed a medial semilunar cartilage lesion in her knee joint. She was seen with swelling and limitation of flexion and extension; movement deteriorated. A Mantoux reaction recorded on three occasions was negative. Arthrotomy revealed a bucket-handle tear of the medial cartilage, which was removed.

Simple bone cysts: ready healing after biopsy—*Mr J. Colquhoun* (Melbourne) showed two cases of simple bone cysts. The first, at the upper end of the fibula and humerus in an Italian child, underwent spontaneous repair after biopsy. The second, a large cyst in the right femoral neck of a child of thirteen, was confirmed by lateral biopsy to be a simple cyst. Six months later the bone was almost normal.

Hydatid cyst of the femur—*Mr A. Hamilton* (Sydney) described a man with an aching knee and a history of syphilis. Radiographs revealed a cyst in the lower end of the femur with considerable surrounding sclerosis. It was found to be due to hydatic disease. He also had a hydatid cyst in the liver.

Skeletal dystrophies—*Mr N. Wilson* (Adelaide) showed a case of osteochondrodystrophy of the Morquio-Brailsford type, and also a case of chondrodystrophy in a child aged twelve. There was an inch and a half of shortening of the right femur and medial rotation of the lower half of the femur from malunion of a fracture. *Mr P. Williams* (Melbourne) asked, in regard to the second case, whether surgical procedures were justified in Ollier's disease. He had had no personal experience. He thought that the valgus deformity in the limb could be corrected by osteotomy.

Orthopaedic surgery in modern China—*Mr H. Barry* (Sydney) described, with excellent colour slides, a recent visit to China with a large representative medical delegation. He had been impressed particularly by the average health of the Chinese people, especially the children, by the modern hospitals that he had seen and their standards of treatment, and by the high standards of hygiene in the parts of the country that he had visited.

Orthopaedic centres in Europe—*Mr E. Fargi* (Melbourne) described a recent tour which he had made of some of the main orthopaedic centres in Italy.

Annual General Meeting—The following officers were elected for the ensuing year: President, Mr J. B. Colquhoun (Melbourne); President-elect, Mr J. Lahz (Brisbane); Honorary Secretary, Mr F. H. M. Callow, 100 Carillon Avenue, Newtown, New South Wales.

SCANDINAVIA

SCANDINAVIAN CLUB FOR SURGERY OF THE HAND

Dr J. Mortens writes: In 1951 a limited group of men from all the Scandinavian countries—orthopaedic surgeons, general surgeons and plastic surgeons with a mutual interest in the field of surgery of the hand—gathered together on the initiative of *Dr Erik Moberg*. And so the rather informal Interscandinavian Club for Surgery of the Hand was established. *Dr Erik Moberg* (Gothenburg) has since the foundation served as president and *Nils Carstam* (Malmö) as secretary.

The club has organised an efficient circulation between members of up-to-date literature concerning hand surgery in its various aspects from all over the world. The photo-prints of papers serving this purpose are later collected at centres in the various countries, so that a library of literature concerning hand surgery is established in all Scandinavian countries.

During the years several gatherings of members have taken place with the club's own agenda in connection with the meetings of the Interscandinavian Surgical Association and meetings of the various countries' surgical and orthopaedic associations.

An " independent " meeting, the first of its kind, was held in Gothenburg in December 1956. About twenty members from the four countries were present. We saw Dr Moberg's new department for " Surgery of the Extremities " (Extremitetskirurgiska Avdelingen, Ekmanska Sjukhuset, Göteborg), how he was about modernising and organising the old hospital into a very efficient unit. Demonstrations of patients were given at this hospital and at a private clinic (Carlanderska Sjukhuset) in the centre of Gothenburg where a department was established for reconstructive hand cases. Discussions in the shape of " round table conferences " and film demonstrations took place in Dr Moberg's private home.

Objective methods of demonstrating useful hand sensibility—*Dr E. Moberg* (Gothenburg) stressed the fact that demonstration of sensibility to touch and pain had no significant bearing on useful hand sensibility which is stereognosis (tactilegnosis). He reported the work done by others and by himself in order to establish an objective method of demonstrating stereognosis and found the sudomotor function helpful in this respect. His method of demonstrating the sudomotor function—the ninhydrin-paper-method—was demonstrated by film and on different patients. He also demonstrated patients in whom flaps were moved—or were to be moved—in order to give sensibility to the pinch.

Dr Lars Önne (Stockholm) commented on a series of nerve repairs in which he had used Moberg's ninhydrin method.

Thumb opposition tendon transference—*K. Bang Rasmussen* (Copenhagen) reported eighty patients—mainly with the sequels of poliomyelitis—operated on at the Orthopaedic Hospital, Copenhagen. Fifteen had poor results. Most cases had been treated by the sublimis transference round—or in—a pulley of the flexor carpi ulnaris tendon. Most failures were due to either a weak sublimis or a wrong insertion of the tendon. He had consequently modified the technique. The sublimis tendon was now most often fixed to the short abductor tendon, thus eliminating the risk of wrong placement of the tendon in relation to the metacarpo-phalangeal joint with subsequent extension or flexion contracture. A reliable function of the short abductor is ensured in this way, and the hand can be opened. The very last rotating movement of the thumb, but the least important, is sacrificed. Twenty-seven patients had been operated upon according to these principles: ten were re-operations. There were only three bad results.

Complications after operations for Dupuytren's contracture—*Dr N. Carstam* (Malmö) had performed 122 such operations during the last three years at the department for hand surgery, Allmänna Sjukhuset Malmö. In three-quarters of the cases a total or subtotal fasciectomy was done; in 10 per cent primary skin grafting was also performed. Seven cases were complicated by haematoma, and in four cases skin necrosis necessitated a secondary skin-grafting procedure. In twenty-two cases stiffness after operation was severe enough to warrant the administration of cortisone or a sympathetic nerve block.

Technique of interphalangeal arthrodesis and operation for Bennett's fracture—*Dr E. Moberg* (Gothenburg) had tried Bunnell's method with crossed wires, also compression osteosynthesis and locking of the joint with a bone graft, and had found them all unsatisfactory in fusing interphalangeal joints. He demonstrated by film the method now in use at his department: a bone peg inserted through a dorsal hole in the proximal phalanx and passed down into the medullary cavity of the distal phalanx. He also showed his method of open reduction and fixation with wires of Bennett's fracture.

MEXICO

MEXICAN ORTHOPAEDIC SOCIETY

The Mexican Orthopaedic Society will hold the Fifth National Congress of Orthopaedics and Traumatology in Mexico City from September 7–13, 1958. The officers of the organising committee are as follows:—President, Dr Rafael Farrera Rojas; vice-president, Dr Xavier Romo Diez; secretary, Dr Ismael Ugalde Nieto; assistant secretary, Dr Benito Jiménez Sandoval; treasurer, Dr Jesús Salas Heredia.

CORRESPONDENCE AND ANNOUNCEMENTS

THE TREATMENT OF PERTROCHANTERIC FRACTURES

Mr Norman Capener writes: In connection with my Annotation on the treatment of pertrochanteric fractures (Journal of Bone and Joint Surgery, **39–B,** 436), Dr E. Compere has drawn my attention to the fact that Neufeld was not the only person involved in developing the idea of the one-piece nail-plate. Dr Compere mentions similar work by Dr E. L. Jewett, who published a paper describing such a device in 1941 (Journal of Bone and Joint Surgery, **23,** 803).

Dr Christopher A. Mason has written to say that, at the turn of the century, John B. Murphy was nailing neck fractures with tenpenny spikes, and that Dr Alfred Gallant has called attention to the angled femoral nail-plate devised by Dr Miller Preston, an Army officer and police surgeon of Denver, Colorado (Fractures and Dislocations—Diagnosis and Treatment, 1915, p. 550 and 551. St Louis: C. V. Mosby Co.).

BRITISH ORTHOPAEDIC ASSOCIATION FUTURE MEETINGS

The autumn meeting will be held at Oxford on October 2, 3 and 4, 1958. The first day will be devoted to an instructional course and on the afternoon of the second day there will be a clinical meeting at the Nuffield Orthopaedic Centre.

The spring meeting 1959 will be held in Torquay and Exeter on April 30 to May 2, 1959. The French and Belgian Orthopaedic Societies have been invited to participate in this meeting.

Book Reviews

OPERATIVE SURGERY. Under the General Editorship of Charles ROB, *M.C.*, M.Chir., F.R.C.S., Professor of Surgery, St Mary's Hospital, London; and Rodney SMITH, M.S., F.R.C.S., Surgeon, St George's Hospital, London. Consultant and Associate Editors: J. Crawford ADAMS, M.D., F.R.C.S., Orthopaedic Surgeon, St Mary's Hospital, London; R. J. V. BATTLE, *M.B.E.*, M.Chir., F.R.C.S., Plastic Surgeon to Queen Elizabeth Hospital for Children, and to St Thomas's Hospital, London; Sir Stewart DUKE-ELDER, *K.C.V.O.*, Ph.D., D.Sc., LL.D., M.D., F.R.C.S., Director of Research, Institute of Ophthalmology, University of London; Ophthalmic Surgeon, Moorfields Eye Hospital, London; Maxwell ELLIS, M.D., M.S., F.R.C.S., Surgeon to the Royal National Throat, Nose and Ear Hospital, London; Ear, Nose and Throat Surgeon to the Central Middlesex Hospital, London; C. M. GWILLIM, M.D., F.R.C.P., F.R.C.S., F.R.C.O.G., Obstetric Surgeon, St George's Hospital, London; Surgeon, Samaritan Hospital for Women, London; Wylie MCKISSOCK, *O.B.E.*, M.S., F.R.C.S., Neurological Surgeon, National Hospital for Nervous Diseases, Queen's Square, St George's Hospital, and Hospital for Sick Children, Great Ormond Street, London; Robert Guy PULVERTAFT, M.B., B.Chir., F.R.C.S., Orthopaedic Surgeon, Derbyshire Royal Infirmary; Surgeon, Harlow Wood Orthopaedic Hospital. 11¼×9 in. London: Butterworth & Co. (Publishers) Ltd. Price £5, 10s. per volume.

Volume IV. Head and Neck with Clearance of Lymph Nodes, Vascular Surgery, Endocrine Glands, with twenty-one contributors. Pp. xiii+378, with many figures. Index. 1957.

Volume V. Orthopaedic Surgery, with sixteen contributors. Pp. xiii+366, with many figures. Index. 1957.

Volume VI. Hand, Amputations, Plastic Surgery, Gynaecology and Obstetrics, with twenty-five contributors. Pp. xiii+123, with many figures. Index. 1958.

The fourth volume deals with operations on the head and neck, the vascular system, and on endocrine glands. Quite the best section is that on vascular surgery, with very complete and helpful descriptions of operations upon the sympathetic ganglia, arterial aneurysms and even the lowly varicose veins: the last being particularly well dealt with. It seems hardly necessary to illustrate a subcutaneous tenotomy of the tendo calcaneus with three line drawings. The part dealing with the surgery of the head and neck is not very impressive, and to have six line drawings to tell us how to remove a wen is hardly complimentary to the reader. Nor does the dissection of tuberculous cervical lymph nodes appear at all familiar to the reviewer who, in the old days, must have done literally hundreds; but they very rarely require operation now, and so surgeons are not so familiar with the condition. Paralysis of the cervical branch of the facial nerve is certainly detectable clinically but fortunately it usually clears up. The descriptions of conservative and radical parotidectomy are good, but the illustrations are less so. It is interesting to read of " tracheostomy," which is right of course, but it sounds odd after our familiarity with tracheotomy. On the whole this is rather a disappointing volume after such a good beginning in the first three.

The fifth volume is devoted to orthopaedic surgery and covers every type of operative technique, with line drawings of every stage. The contributors form a very representative group of British surgeons in which the younger members are in the majority.

Some valuable information is got in the beginning on special equipment, much of which is described in detail, as, for example, that a chisel is bevelled on one side and flat on the other; that it is important to remove a tourniquet; what plaster-of-Paris is; and such like. A brief review of growth disturbance of the leg is interesting, though few would remove and replace a long cortical segment of the tibia in the expectation of much stimulation of growth. Femoral lengthening is well described but no mention is made of the more usual tibial lengthening, nor of stapling for the retardation of growth. An excellent description is given of occipito-cervical fusion. This is well illustrated and very helpful. The section on spinal fusion deserves equal praise. The Putti-Platt operation for recurrent dislocation of the shoulder is fully described on eight pages and is preferred by the author to the more anatomical Bankart one (one half page) because it is easier to perform. It is said that the results of the Bankart operation are not superior to the Putti-Platt. That may be, because in this operation as described there is no "rawing" of the anterior lip of the glenoid—a rather important point in achieving a good result. When the author says the Nicola operation has practically been abandoned it seems hardly worth while even to mention it.

In the section on hip conditions, congenital dislocation and slipped epiphysis are good though a Smith-Petersen nail for the latter seems on the big side. Arthrodesis of the hip is clearly described.

The Brittain method is included; the more usual and safer postero-lateral approach under vision should also be described for those who are likely to read the book. The popular arthroplasty of the hip is satisfactorily related, and the many methods are well described. An unusual approach is used and the Moore type of prosthesis is preferred. Indeed, Judet gets scant recognition. Charnley's operation of central dislocation "arthrodesis" has apparently a double aim because, if bony ankylosis is not achieved, a fibrous one is just as satisfactory. Indeed, the basic feature or aim is the central shift of weight bearing. It is wise here to read that the provision of cross-grouped blood is essential.

The knee operations are dealt with fully and adequately. The illustration of "shelling out" the patella for its removal will surprise the young surgeon when he comes to do it. It looks easy in the illustration, but somehow it is very tedious. An excellent description is given of antero-lateral decompression in cases of tuberculosis of the spine—as might be expected from its author and incidentally its inventor. The treatment of fracture-dislocation of the spine is clear, precise and so well illustrated that the reader should be well able to carry it out.

A very good part of the book is that on minor operations on the foot and especially the toes. It is good to see metatarso-phalangeal arthrodesis given as an alternative to Keller's operation, and one welcomes, too, the good description of Lambrinudi's operation for claw foot. As the author says, this operation is ingenious and effective.

The illustrations throughout the book are of a very high quality and, with the excellent text, should make these orthopaedic operations relatively easy—as indeed they are. It would have been helpful if the various authors had given more of their own opinions and preferences where various operations are described for the same condition. The volume is a great credit to those authors who are responsible, no less than to the artists, who may well be proud of their work.

The sixth volume deals with surgery of the hand, amputations, plastic surgery, and gynaecology and obstetrics. The part dealing with hands is one of the best, and many operations coming into the orthopaedic speciality are exceedingly good. Two operations for first carpo-metacarpal arthritis are described by different authors but no help is given as to which is the better. A quite wonderful description is that on hindquarter amputation, written by the acknowledged authority on the subject. One wonders if his total has reached the century yet! Much space is taken up by a section on trauma to the hand and another on amputations of fingers, and although both are good some of the indications for amputation of fingers after injury would be extremely useful. One would be a little apprehensive of the use of local anaesthesia in infections of the hand. This volume is well up to the high standard of the preceding ones and the completed work will be a wonderful asset to the young surgeon and to the examination candidate.—Walter MERCER.

THE INFANTILE CEREBRAL PALSIES. By Eirene COLLIS, Assistant to the Director of the Cerebral Palsy Unit, Queen Mary's Hospital for Children, Carshalton; W. R. F. COLLIS, Director of Paediatrics, Rotunda Hospital; Physician, National Children's Hospital, Dublin; William DUNHAM, Physician to the Department of Physical Medicine, Charing Cross Hospital; L. T. HILLIARD, Consultant Psychiatrist and Physician Superintendent, Fountain Hospital for Mentally Defective Children, London; and David LAWSON, Physician Superintendent and Consultant Paediatrician, Director of Cerebral Palsy Unit, Queen Mary's Hospital for Children, Carshalton. Foreword by Sir Francis WALSHE, Consulting Physician, University College Hospital and National Hospital for Nervous Diseases, Queen Square. $8\frac{1}{2} \times 5\frac{3}{4}$ in. Pp. xi+100, with 2 tables. Index. 1956. London: William Heinemann Medical Books Ltd. Price 15s.

The subject of cerebral palsy tends at the present time to be hemmed in by complex theories and esoteric therapies. Into this background the present work blows a refreshing air of common sense. The incidence of cerebral palsy is 2 in every 1,000 live births: a quarter of the patients can be educated like normal children, another quarter are so mentally subnormal as to be ineducable, leaving half who will require special educational provision for the combined mental and physical disability. The total number of children under fourteen is approximately 450 per million of the population of England and Wales. The consequent big problem could, according to the authors, be dealt with adequately in big centres of population within the family by a service providing early diagnosis, continuity of supervision and advice in the management and changing needs of children so afflicted. Common sense and physiological understanding are the dominating principles laid down by W. J. Little a hundred years ago. As Walshe says, "some parents are willing to hand the child over to a team of white-coated technicians, and thus to place their own responsibilities in commission . . . they cherish a vain hope, for the mother is the natural and essential trainer of her child whether it is normal or the subject of cerebral palsy." Is Walshe justified, however, in saying that "orthopaedics and physiotherapy, as we see them to-day, do not constitute a training of the child upon physiological principles and are not

optimally designed to meet this situation"? If this were entirely true it would be a sad reflection on a department of *medicine* which counts W. J. Little and Robert Jones amongst its pioneers. No one should regard orthopaedics only as a " surgical " subject.

The writers of this book have hard things to say about parents' organisations who use funds indiscriminately for mentally deficient children and join cerebral palsy associations as part of a refusal to accept the real situation. For economic as well as humane reasons it is well to emphasise the value of work in the home and in day schools, particularly for infants. In big centres of population this seems sensible, but in country districts and for older children the need for residential schools will remain.

This book is produced by an eponymous committee to further the wise and humane teaching of W. J. Little.—Norman CAPENER.

LES SPONDYLOLISTHESIS. By W. TAILLARD, Privat-docent d'orthopédie à l'Université de Zurich. Préface by Georges HUC. 10×6¾ in. Pp. xii+188, with 15 plates and 56 other figures. 1957. Paris: Masson et Cie, Editeurs. Price 2,000 fr.

Spondylolisthesis is a subject of fascinating interest. Arising as an abnormality of bony structure, minor in extent but having major and sometimes alarming consequences, it nevertheless holds no threat to life. What is perhaps not sufficiently realised is that it occurs in the circle of articulations surrounding the centre of gravity of the standing and walking body and, as with subluxations of the hip and coxa vara, its relation to this focal point of stress is a dominant feature in the evolution of deformity. It is obvious that if there is any serious mechanical defect in any of the constituents of this circle of articulations the others must all be affected and eventually will present compensatory change. This is particularly well illustrated by spondylolisthesis. Furthermore the lesions of these other articulations might well illuminate the etiological problems that this deformity presents.

The present work is one of the best surveys of spondylolisthesis that have appeared, particularly because of the author's reasoned discussion of the etiology—congenital, traumatic, tropho-static and dysplasic. He totally discredits the congenital theory, but agrees that though the causal influence of trauma is uncertain it must, with static factors, play an important part in the evolution of the condition. A nice description is given of one or two cases in which such influences did in fact cause spondylosis at the upper end of the grafted area after lumbo-sacral fusion for spondylolisthesis at the usual lower level. For the present, Taillard feels that only the theory of dysplasia, influenced by a genetic factor, explains the observed facts in a satisfactory manner. From this review are excluded cases without neural arch defect (" pseudospondylolisthesis "), and other forms of vertebral sliding, such as fracture-subluxations and those due to inflammatory or neoplastic lesions. Treatment is very thoroughly discussed. Reduction is described as a possibility. The cases reported by Jenkins, Nicoll and Watson-Jones are mentioned; and a particular description is given of the earliest known case of reduction, that of Scherb in Zurich (1921), which is of interest because carried out by distraction in extension, a method which the reviewer also has found effective. Reduction of the deformity is almost impossible to retain. Posterior grafts do not offer much chance of success. The surgical treatment of the unreduced displacement by either posterior or anterior grafting is fully discussed. Posterior grafting has a 50 per cent expectation of pseudarthrosis of the graft. Anterior grafting has risks: the figure of seven deaths in seventy-nine cases is noted from the literature. Sensible conservative treatment is described. No mention is made of Girdlestone's original idea of fixing grafts between the transverse processes of the fourth lumbar vertebra and the ilium. The literary net has been cast very wide. It includes all the classical work, and amongst the moderns are J. F. Brailsford, R. I. Harris, B. H. Burns, I. Macnab, P. H. Newman and G. A. G. Mitchell to mention a few of those workers in whom we in Great Britain have a special interest. Your reviewer's conceit is slightly pricked by finding that his own work has been completely overlooked.

This volume is produced in the high standard we expect of Masson & Cie; its author is Swiss and comes from the school of Schulthess and Scherb at Zurich.—Norman CAPENER.

ARTHROPLASTY OF THE KNEE USING AN ENDOPROSTHESIS. By Börje WALLDIUS. 9×6¼ in. Pp. 112, with 102 figures and 3 tables. 1957. Copenhagen: Ejnar Munksgaard. Acta Orthopaedica Scandinavica, Supplementum XXIV (24). Price Dan. kr. 25.00.

The author surveys, in a very interesting monograph, the development of arthroplasty of the knee from 1853. He divides the methods into resection, arthrolysis, interposition and replacement operations. The published results of arthroplasty from 1914 to 1953 are tabulated, and it is suggested that good

results were achieved in 46 per cent (412 out of 896). It is of course often very difficult to compare various surgeons' results because methods vary. Judged by past experience, the indications for this operation are limited. It should be carried out only when other methods of treatment are unlikely to succeed. By general agreement it has usually been reserved for cases of ankylosis of both knees, or the hip and knee in the same limb. The patient should be between twenty and forty years of age; he should have good muscles and sound skin over the joint. It was thought undesirable to carry out the procedure after inflammatory conditions.

Walldius has used his prosthesis to replace thirty-two knee joints in twenty-six patients—twenty-nine for rheumatoid arthritis, two for severe arthrosis deformans and one for post-traumatic ankylosis. Excellent results were obtained in twenty-three patients (79 per cent) with rheumatoid conditions. Freedom from pain was achieved with 75 per cent of the prostheses; the average range of active movement was 84 degrees, with full stability and improved gait. This compares very favourably with his assessment of previous results by other surgeons, namely 46 per cent of good " results." He

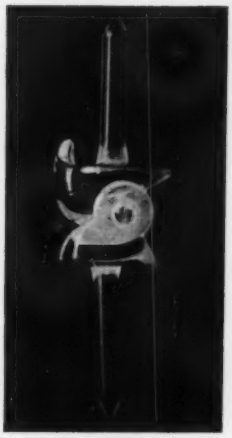

FIG. 1*a*

FIG. 1*b*

rightly believes that restoration of function is a secondary consideration to the relief of pain. The average age of his patients was fifty-three years, one being seventy-nine, the youngest twenty-nine. The series comprised seventeen women and nine men. In the past it has been emphasised that a patient should have the right mentality and the desire for the procedure to succeed, but Walldius found that many of his patients were depressed because of their condition and that the operation gave them new hope and improved their mental state. His period of observation has ranged from seven months to four years ten months.

The prosthesis is made of polymethyl methacrylate. It consists of a femoral and a tibial part, each carrying an intramedullary pin which in the earlier implants was reinforced with a stainless steel rod (Figs 1*a* and *b*, and 2). The two components are joined by a stainless steel hinge pin. Five degrees of hyperextension and 90 degrees of flexion are allowed. The implant is designed to be end-bearing on the femur and tibia, the tibial and femoral plateaux being parallel when the joint angle is 180 degrees. Axial rotation on the tibia and femur is prevented by an anterior lip on the femoral part and a posterior lip on the tibial component. The femoral lip is continued upwards to carry the patient's patella. It seems likely that these lips and the intramedullary pins will fail in time because acrylic resins have not the requisite mechanical properties for this type of implant and the stainless steel components are likely to present problems of corrosion. He has now wisely decided to have the implant made of cobalt-chrome alloy.

Laboratory tests are described which showed that during movement of a non-lubricated joint a rise of temperature of 18 degrees centigrade was possible. In the body the implant would be cooled to some extent by tissue fluids. Nevertheless it is conceivable that a joint could " run hot " with undesirable effects on the surrounding tissues.

It would seem unwise to have limited flexion to 90 degrees and extension to 5 degrees: to limit movement by a mechanical stop within the implant is likely to throw undue loads on the lips and intramedullary pins. The stability of an artificial knee joint must depend on the development of

adequate muscle control and fibrous tissue formation. An operative technique that is kindly to musculo-aponeurotic planes has doubtless contributed to the author's success.

Special tools have been devised to facilitate insertion of the implant. Many surgeons in the past, particularly in the case of the Judet prosthesis, have tried to carry out a technique without the tools that the person who developed the operation found necessary. Implant surgery is, in fact, precision " bone carpentry." Too much reliance has often been placed on nature's capabilities of adjustment and repair.

The knee is approached through a transverse curved incision, its apex over the tuberosity of the tibia and starting and ending 2 centimetres proximal to the medial and lateral aspects of the knee joint. The skin flap and capsule are reflected together so as not to interfere with the blood supply to the skin. The ligamentum patellae is reflected with the tibial tuberosity. The patella is retained and fashioned as nearly as possible to the form of the anterior lip of the prosthesis. Between 10 to 15 millimetres of the tibia and 23 to 28 millimetres of the femur are resected, the bones being divided strictly at right angles to the axes of their shafts. Channels are bored in the medullary cavities with a specially devised auger and measuring block, which ensure the correct fit of the two components. The hinge pin is inserted and locked in position. With the knee in the extended position a plaster-of-Paris cast is applied over a well padded cotton wool dressing. The stitches are removed in two to three weeks at which time passive movements are begun. Weight bearing is allowed after six to eight weeks when the patient should have muscle control of the joint. Six months after the operation patients are usually able to flex the knee to a right angle. The average stay in hospital was five months eight days.

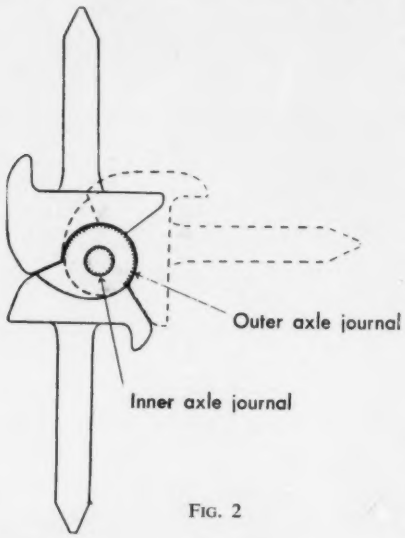

FIG. 2

Complications have included: one case of pulmonary embolism; one case of thrombosis; two cases of wound disruption; four cases of local skin necrosis; all with final healing. Infection caused one death, two amputations and, in four cases, removal of the implant followed by arthrodesis. In five cases the implant broke. Although the tibial medullary pin broke in one patient with a bilateral arthroplasty, adequate function was retained. These mechanical failures would be unlikely if a cobalt-chrome implant were used. No implant has so far loosened appreciably, although Walldius states that " under the load of the body weight the prosthesis sways a few millimetres in its covering of connective tissue." It is hoped that he will review his cases in the years to come because it is unlikely that this method of fixation will be permanent. The case notes and radiographs of the twenty-six patients are published.

Further improvements in arthroplasty are probably dependent on replacement of both surfaces of a joint. It is difficult to imagine that nature can re-form a suitable moving bearing surface on bone when only one component of the articulating surface is replaced by a prosthesis. What might be termed a "static" load-bearing area or "table" can develop on which the implant rests. The prosthesis that Walldius describes is based on this premise, and his monograph should be read by all who are interested in orthopaedic prosthetics.—John T. SCALES.

CONNECTIVE TISSUE. A Symposium organised by The Council for International Organisations of Medical Sciences. Established under the joint auspices of UNESCO and WHO. Edited under the direction of R. E. TUNBRIDGE, the University of Leeds; by Madeline KEECH, the University of Leeds; J. F. DELAFRESNAYE, C.I.O.M.S., Paris; and G. C. WOOD, the University of Leeds. 9×6 in. Pp. xii+371, with many figures. Index. 1957. Oxford: Blackwell Scientific Publications. Price 42s.

Professor Astbury in his opening chapter quotes Sydney Smith's famous remark: "I never read a book before reviewing it; I find it prejudices the mind." Having read this book from cover to cover, I confess to being thoroughly prejudiced and declare this the best available publication on connective tissue.

In July 1956 the Council for International Organisations of Medical Sciences held a symposium in London which was attended by most of the chemists, physicists and medical men who have contributed to our knowledge of the biochemistry and structure of connective tissue. The proceedings of this meeting are here published under the editorship of Professor R. E. Tunbridge, who presided.

Each contributor gives a short account of recent research followed by an exposition of current hypotheses—this is always most convincing until one reads the critical comments made by the other experts. These corrective remarks are invaluable to the inexpert since they show what is generally acceptable and what is not.

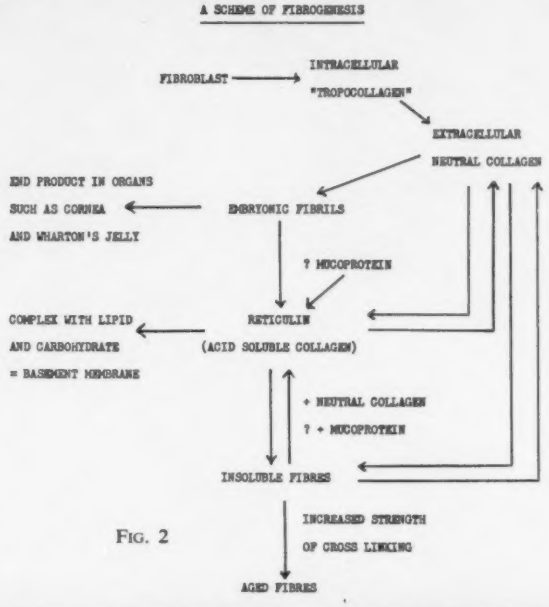

FIG. 2

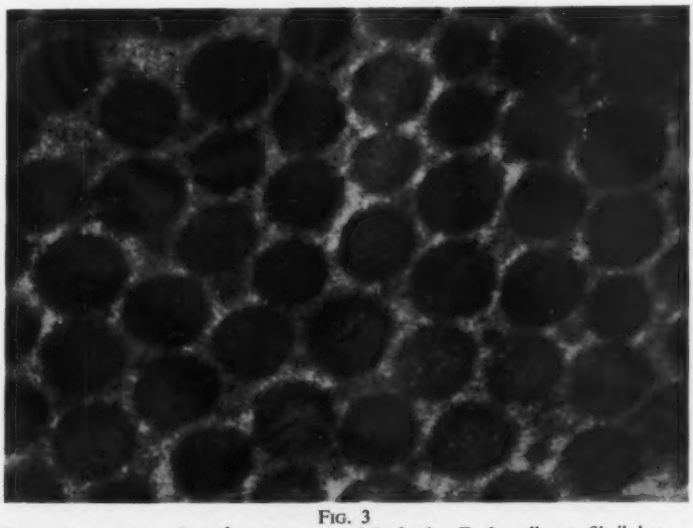

FIG. 3
Transverse section of tendon from an adult fowl. Each collagen fibril has a distinctive outer boundary and is invested by interfibrillar material. (×150,000.)

The structure of collagen is discussed by such authorities as W. T. Astbury, R. S. Bear, R. Reed, W. Grassmann, W. Schwarz and F. Verzar. The picture that emerges is of a basic protofibril composed of three polypeptide chains wound round each other in a coiled triple helix. These protofibrils are in turn twisted together to form the familiar cross-striated fibrils seen on electron microscopy. At yet a

higher level the anatomical tendon bundles also show a coiled structure. Thus the nice straight tendon fibre is really a fantastically twisted structure like some gigantic rope.

K. H. Gustavson marshals convincing evidence for the importance of hydroxyproline in stabilising the collagen fibre and we can now contemplate the fascinating possibility that our collagen may become unravelled through failure of some simple chemical reaction such as the hydroxylation of proline. Chemical evidence concerning the precise sequence of various amino acids in the peptide chain of collagen is presented by W. Grassmann, and it seems likely that all the details of the collagen molecule will be worked out before long.

Collagen metabolism is discussed by D. S. Jackson, J. Gross and V. N. Orekhovitch. All are agreed that although the main mass of collagen is metabolically inert there is a highly active and more soluble precursor which can be extracted from tissues in which collagen fibres are being laid down or removed. Furthermore, the formation of this precursor stops abruptly with starvation, scorbutus or any other disturbance that halts growth. The general scheme of fibrogenesis as proposed by Jackson is illustrated (Jackson, Fig. 2, p. 73).

The proceedings were by no means monopolised by the collagentsia. G. Asboe-Hansen and B. Sylvén discuss mast cells and their relation to heparin and other polysaccharides, and Karl Meyer gives a masterly exposition of the structure of the chondroitin sulphates. There is also new information about the protein component of the interfibrillary ground substance. According to A. Neuberger it is partly serum albumen derived from the circulating plasma, but Joan Bowes and Helen Muir both present evidence of other non-fibrous ground substance proteins that must be reckoned with. Sylvia Fitton Jackson's electron micrographs of transverse sections of tendon demonstrate strikingly this interfibrillary material and the lack of hexagonal close packing (Fitton Jackson, Fig. 3, p. 84). The nature of reticulin is admirably presented by A. H. T. Robb-Smith; and there are brisk discussions on elastin and its relation to and interconvertability with collagen by D. A. Hall and S. Partridge, followed by I. Bango and J. Balo on elastases; indeed there are so many important contributors that it is impossible to mention all of them.

This is of course biochemistry for biochemists, so that the average clinician will find the going pretty tough, but for those who want authoritative up-to-date information about connective tissue this book is a " must."—J. H. KELLGREN.

LEHRBRUCH DER CHIRURGIE. By H. HELLNER, Direktor der Chir., Univ.-Klinik Göttingen; R. NISSEN, Direktor der Chir., Univ.-Klinik Basel; and K. VOSSSCHULTE, Direktor der Chir., Klinik der Justus Liebig-Hochschule, Giessen. With the collaboration of thirty other contributors. $10\frac{1}{2} \times 8$ in. Pp. xxxvi+1,060, with 596 figures in 914 Einzeldarstellungen. Index. 1957. Stuttgart: Georg Thieme Verlag. Price DM 84.

This is a very comprehensive textbook of surgery covering all the surgical specialities, produced by thirty-three authors, German and Swiss, most of them occupying important chairs. There is a vast amount of information in the book and it is very well set out. The illustrations are clear and well produced. The text is in general simple and most of the chapters are so clearly written that they might have been intended for readers whose mother tongue is not German. Most of the chapters are well up to postgraduate level. References are liberal, many of the authors being obviously familiar with non-German literature but some quoting very little British or American work. Nearly all the up-to-date surgical techniques are described, and the proportions of space allotted to different specialities are in general very wise though perhaps orthopaedics is less liberally dealt with than it deserves, receiving only about 25 per cent of the available space. A very useful appendix gives the percentage disability occasioned by amputation at various levels in the upper and lower extremities; these conform very closely to British standards. The book as a whole affords very instructive reading for any postgraduate or even senior undergraduate who has a working knowledge of German.—Ian AIRD.

THE PROXIMAL END OF THE FEMUR. Investigations with Special Reference to the Etiology of Femoral Neck Fractures. By Stig BACKMAN. $9\frac{1}{2} \times 7$ in. Pp. 166, with 70 figures. 1957. Stockholm: Acta Radiologica, Supplementum 146. Price Sw. kr. 35.

This monograph is a new study of the anatomy and biomechanics of the femoral neck with particular reference to the etiology and treatment of intracapsular fractures.

In the first chapter a careful analysis is made of the various axes existing in and between the femoral neck and the shaft, and from this emerges what Backman calls the *principal plane* of the neck.

The neck of the femur, being ellipsoidal in cross-section, has the plane of its major axis directed downwards and backwards. This plane contains the great trochanter, the centre of the femoral head and the lesser trochanter, and in fact the trajectôries that produce the calcar femorale. It is in this plane, rather than in the simple coronal plane, that strains and stresses on the femoral neck ought to be visualised.

The motive which dominates the rest of the book, though without completely excluding instructive side issues, is the attempt to decide, by mathematical analysis and by direct experiment, whether intracapsular fractures of the femoral neck are the result of direct falls on the great trochanter or the result of torsional strains before the patient has fallen to the ground. An impressive body of evidence is produced to support the view that direct falls on the great trochanter are the most common cause of intracapsular fractures. It is conceded that a fracturing force of this kind would tend to force the head into the valgus direction rather than into varus, and also that experimental fractures produced on cadaveric bones by this type of force do not look quite the same as fractures encountered in clinical practice. It is suggested that gross varus deformity is a secondary mechanism from muscle contraction, and experimental evidence is produced to suggest that the soft parts of the buttock may support the neck of the femur at the moment of impact and so modify the shape of the fracture.

To test the possibility that fracture of the femoral neck might be caused by contraction of the external rotator muscles, direct measurements were made of the force they produce *in vivo*, and Backman calculates that three or four times the force generated by the external rotators would be necessary to fracture the femoral neck by a force acting in this direction.

The mechanical analysis of stresses and strains in the femoral neck leads to highly involved mathematics which will be over the heads of most orthopaedic surgeons because it is necessary to consider the femoral neck as a tube with an elliptical cross-section having walls that are thicker below than above.

This is a very important work for those engaged in biomechanical research on the femoral neck. What a pity it is that the value of these elaborate mathematical computations cannot be tested by clinical evidence which would decide once and for all whether fractures of the femoral neck are caused by direct or by indirect violence!—John CHARNLEY.

THE GENESIS OF THE RAT SKELETON. A Laboratory Atlas. By Donald G. WALKER and Zolton T. WIRTSCHAFTER. Photography—Dean ALTMAN; Calligraphy—Lloyd J. REYNOLDS. 18 × 12 in. Pp. iii+59, with charts and photographs. 1957. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 57s. 6d.

MICRORADIOGRAFIA OSSEA. SVILUPPO E ACCRESCIMENTO DELLO SCHELETRO UMANO. CRANIO E COLONNA VERTEBRALE. (Microradiography of Bone. Development and Growth of the Human Skeleton. Cranium and Vertebral Column.) By Giorgio PREVEDI and Marco MARCATO. 12 × 9 in. Pp. 144, with 70 figures. 1955. Bologna: L. Cappelli (Publishers).

Students of skeletal development will be interested by these two recently published atlases. The first, from the Veterans' Administration Hospital and the University of Oregon Medical School at Portland, Oregon, deals with the development of the rat skeleton from the initial appearance of ossification centres at about seventeen days after conception to the more or less completely outlined skeleton at about thirty to forty days after birth. It consists of an undocumented series of illustrations, most of which are photographs of intact bones prepared by the methods introduced by Mall in 1902, the calcified tissues being stained by alizarin red-S after maceration in potassium hydroxide, and the specimens being finally mounted in glycerine. There are also a few radiographs of complete skeletons of developing rats, but the quality is poor.

This atlas is a rather cumbersome volume 18 inches by 12 inches in size. Most of its large pages show only one much enlarged photograph, together with an unnecessary line drawing and some large and elegant lettering: the page can be comfortably viewed from a distance of about 4 feet. To the reviewer it would seem that a more modest method of presentation could well have kept the work within the confines of a standard sized and more easily handled book, and also have allowed the inclusion of a much needed text. It is to be regretted that no histological information or illustrations are included in this work: it is only possible to learn from it the gross outline of the various calcified units of the skeleton without information about their microscopic structure or the cellular processes which are responsible for their growth.

The second work, from the Departments of Radiology and Normal Anatomy of the University of Palma in Italy, illustrates the appearances of the bones of the skull and of the vertebral column in the human embryo as seen in foetuses from the second to third and fourth to fifth months. The illustrations

are all microradiographs, the outline of the calcified tissues being shown solely by means of their absorption of soft x-rays.

While these preparations show very beautifully the outline of calcified structures, and give an idea of their changing architecture, it is again disappointing that they are not combined with histological illustrations. But it is most valuable documentation all the same. The microradiographs show the individual structural characteristics of the various bones: they contrast the structural patterns resulting from membranous and endochondral ossification, and they are combined with a text which relates the authors' findings to the previous anatomical literature. The book is to be welcomed as an important step towards the adequate documentation of the development of the human skeleton.—H. A. SISSONS.

FRAKTUREN IM KINDESALTER. By Hans RETTIG, Oberarzt an der Orthopädischen Klinik und Poliklinik der Freien Universität Berlin im Oskar-Helene-Heim. $9\frac{1}{4} \times 6\frac{1}{2}$ in. Pp. 92, with 196 figures in 330 einzeldarstellungen. Index. 1957. Munchen: Verlag von J. F. Bergmann. Price DM 26.80.

This short volume can only be regarded as an outline of bony injury in childhood; within these limits it is succinct and well illustrated. For the beginner, however, it lacks the details necessary to avoid error; thus there is no emphasis on the speed of union in childhood and the need for obtaining

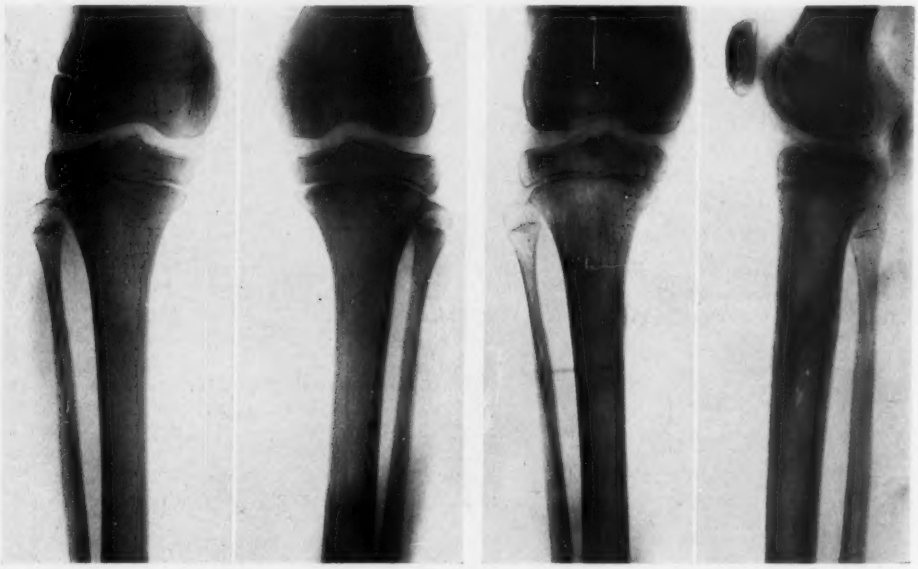

FIG. 1 FIG. 2

Figure 1—Comparative radiographs of both legs. No obvious structural changes between the right and left leg in a female child aged eleven. Figure 2—The right leg of the same patient two months later. At the junction of the upper and middle third of the tibia the bony structure is thickened. In this region there is increased periosteal new bone; running transversely through the altered bony structure is a thin line of decreased density (Looser's node).

anatomical reduction after seven to ten days if conservative methods are to succeed. Though lines of treatment are indicated, none is illustrated or described in any detail.

The book begins with a very short general section, from which the classification of epiphysial injuries may be chosen as a good example of style. These are divided into:—i) Partial separation without displacement, ii) Partial separation with displacement, iii) Fractures of the epiphysis, iv) Epiphysial separation without fracture, v) Epiphysial fracture-separations (the common lesion), vi) Para-epiphysial fractures.

In contrast to these detailed outlines in the general section, there is, for example, in the special section on the elbow, no corresponding detail in the description of the separations that occur or the methods of recognition. Emphasis is generally upon conservative treatment. Many authors' names

and their methods of treatment are quoted in the text, and it is sometimes difficult to find among them the method used or recommended by the author himself. The volume is thus unsuitable for the beginner and has insufficient detail for the experienced. It nevertheless has an interest and appeal, largely due to the beautiful series of radiographs with which it is illustrated. The Continental references are full and up to date. References in English are few and almost wholly American.—J. G. BONNIN.

PEDIATRIC X-RAY DIAGNOSIS. A Textbook for Students and Practitioners of Pediatrics, Surgery and Radiology. By John CAFFEY, A.B., M.D., Professor of Radiology, College of Physicians and Surgeons, Columbia University. Third edition. 10½×8 in. Pp. xxiv+1,059, with 1,267 figures. Index. 1957. Chicago: The Year Book Publishers Inc. Price $28.00.

Dr Caffey's textbook on paediatric radiology now appears in a third edition only eleven years after its original publication. It had already become a standard work of reference in the radiological diagnosis of diseases of children and this new volume, which is most handsomely produced, has been necessitated by the very rapid progress of knowledge in this field. It has been expanded to over a thousand pages with no fewer than 1,267 illustrations. It covers virtually the whole subject, only excepting certain specialised techniques such as myelography. The author deplores inadequate

FIG. 1027

FIG. 1028

FIG. 1029

Figure 1027—Neonatal contusion of the femur with massive cortical thickening and lateral displacement of the ossification centre of the distal epiphysis on the fourteenth day of life. The patient was delivered by breech extraction and a soft mass was evident in the right thigh soon after birth; this swelling gradually became smaller and harder. At no time was the skin over the swelling discoloured. The rest of the skeleton was normal roentgenographically. A, frontal, and B, lateral projection. Figure 1028—Neonatal contusion of the femur with long, massive external cortical hyperostosis on the twenty-eighth day of life in a patient delivered by breech extraction. Traumatic lesions of this kind, especially when multiple, have been confused with syphilis of the diaphyses, scurvy and infantile cortical hyperostoses. Figure 1029—Infantile contusions of the radius and ulna with long, massive external cortical thickenings one month after the infant, four months of age, was jerked upward by his arm to prevent him from falling off a table. The forearm became swollen a few hours after the injury. At first the mother denied that the patient had suffered injury at any time, but told of the injury on direct questioning in the x-ray department after this film was made. This case illustrates the unreliability of the history for trauma to infants by mothers and nurses when the usual casual history of trauma is taken.

knowledge of normal appearances, which is clearly of essential importance before diagnosis of the abnormal is attempted. Therefore each section of the book, in which pathological processes are treated on a regional basis, is prefaced by an adequate account of the normal anatomy, growth, development and radiological appearance. Such accounts are essential for basic knowledge and are also of considerable value for the purpose of reference.

From the orthopaedic standpoint the subjects of importance receive particularly full consideration. In fact, more than half the book is concerned with the skeletal system, with a very complete account of bone radiology. The text is supported excellently by the illustrations, which include many photographs of clinical subjects and pathological specimens, line drawings and a large number of radiographs. These are reproduced in the negative. To each subject is attached a useful list of modern references. Recently recognised pathological entities are described. These include, of course, the condition which is already widely associated with the name of the author—infantile cortical hyperostosis—and also one to which he has more recently drawn attention, that of the bizarre effects of trauma in infancy, to which the name of traumatic cortical hyperostosis has been given. The diagnosis of this condition may be made by one familiar with the appearance, even when, as so commonly is the case, the history of trauma is suppressed by the mother or other custodian of the injured child. Other skeletal conditions to be described for the first time in this edition include hypophosphatasia and oxalosis. In addition, the descriptive text of a number of more familiar diseases has been revised and brought up to date. An entirely new section has been included on dysplasia and congenital dislocation of the hip. Bone radiology in children is thus excellently covered. This is an outstanding work which is well worth a place in any orthopaedic library or radiology department.—R. O. MURRAY.